Sustainable Futures 9 (2025) 100580

Contents lists available at ScienceDirect

Sustainable Futures

journal homepage: www.sciencedirect.com/journal/sustainable-futures

Scientific and strategic foresighting: The trajectory of sustainable development (on the example of Ukraine's energy security)

Yurii Kharazishvili [a,b,*], Yuriy Bilan [c,d,**], Oleksandr Sukhodolia [e], Olena Grishnova [f], Halyna Mishchuk [g]

[a] Institute for Sustainable Development and International Relations, WSB University, 1C Zygmunt Cieplak St, Dabrowa Gornicza, 41-300, Poland
[b] Institute of Industrial Economics of National Academy of Sciences of Ukraine, Maria Kapnist St. 2, Kyiv, 03057, Ukraine
[c] Faculty of Economics and Management, Czech University of Life Sciences Prague, Kamycka 129, Prague, 165 00, Czech Republic
[d] Academic and Research Institute of Business, Economics, and Management, Sumy State University, 2 Rymskogo-Korsakova St, Sumy, 40007, Ukraine
[e] National Institute for Strategic Studies, Pyrohova St 7a, Kyiv, 01054, Ukraine
[f] Taras Shevchenko National University of Kyiv, Volodymyrska St 60, Kyiv, 01033, Ukraine
[g] Faculty of Economics and Business Administration, Vilnius University, Sauletekio av. 9 (II building), Vilnius, 10222, Lithuania

ARTICLE INFO

Keywords:
Scientific and strategic foresighting
Indicators
Thresholds
Integral index
Identification
Strategizing
Sustainable development
Energy security

ABSTRACT

The emergence of the concept of sustainable development of society has prompted the search for national approaches to its management. The application of energy potential by individual countries as a tool of political influence requires a review of the approaches to analyzing the state of affairs in the field of energy security and scientific justification of strategic scenarios for maintaining the trajectory of sustainable development. The **goal** of the article is the further development of the model for analyzing a specific area of management in the security dimension and the methods of strategizing the development of such an area – scientific and strategic foresight for the development of strategic scenarios for post-war recovery using the example of Ukraine's energy security. To achieve the research goal, the concept of sustainable development in the security dimension was used, which includes the methodology for identification and strategizing based on the new principle "the trajectory towards a future determines the future" through solving the inverse problem of decomposing integral indices using adaptive regulation methods from control theory. The methods of integral evaluation, stochastic methods for determining the boundaries of safe existence (applied systems theory, *t*-test methods, cluster analysis), determination of dynamic weighting coefficients using principal component methods and sliding matrices, decomposition of integral indices, and denormalization of indicators in natural units of measurement are also applied. A model of energy security has been developed, which includes seven components and 47 indicators, including shadow indicators. The analysis concept involves first studying each individual component within a unified whole, followed by analyzing energy security as a whole – an identification stage for the current level of security. Subsequently, the sustainable development trajectories are built towards the defined goals, and the whole is decomposed into components that ensure the achievement of the set goals – strategizing. The elements of scientific novelty in scientific and strategic foresighting technology are formulated, which operate in the following modes: structural evolution, projected structural transformation – rapid structural transformation, and balanced sustainable development. The mechanism for regulating the speed of structural restructuring through the regulation of constraints has been identified. Within these modes, models for the development of Ukraine's energy sector in the post-war period have been developed and studied: evolutionary development, green transition, and energy supply resilience for consumers.

* Corresponding author at: Institute for Sustainable Development and International Relations, WSB University, 1C Zygmunt Cieplak St, Dabrowa Gornicza, 41-300, Poland.
** Corresponding author at: Faculty of Economics and Management, Czech University of Life Sciences Prague, Kamycka 129, Prague, 165 00, Czech Republic.
E-mail addresses: yuri_mh@ukr.net (Y. Kharazishvili), yuriy_bilan@yahoo.co.uk (Y. Bilan).

https://doi.org/10.1016/j.sftr.2025.100580
Received 30 August 2024; Received in revised form 18 March 2025; Accepted 26 March 2025
Available online 28 March 2025

1. Introduction

Strategizing is generally understood as the process of multidimensional autonomous management of development, where long-term strategies of various external strategic players are taken into account. In contrast to them, strategies are developed (strategizing) and implemented (planning) to achieve desired goals in the security dimension. Solving the problem of developing a scientifically grounded development strategy for each country in the context of dynamic changes in the global security and economic environment is the most important task of today for ensuring technological leadership in priority industries (such as energy), creating new high-paying jobs, and guiding the country onto the trajectory of advanced sustainable development based on innovation.

Well-known tools for strategizing include forecasting and foresight (foresight – prediction), which use the same methods: the Delphi method, identification of critical technologies, scenario development, expert panels, SWOT (strengths, weaknesses, opportunities, and threats) analysis, econometric modelling, brainstorming, regression analysis, extrapolation, simulation modelling, multi-criteria analysis, etc. In other words, the vision of the future is mainly based on expert assessments and correlation-regression analysis. Neither classical forecasting nor foresight provides an understanding of how the components, indicators, and macroeconomic indicators should change to achieve the desired goals because they rely on the principle that “the past determines the future." However, the future does not continue the past but takes on fundamentally different forms and structures.

Known approaches to classical forecasting of the dynamics of integral indices using polynomials discredit econometric modelling in general and obscure the complexity of such multidimensional concepts as sustainable development and security. The use of expert assessments involves subjectivity and does not exclude fundamental errors. The use of SWOT analysis is a necessary step but entirely insufficient for substantiating strategic orientations for the future. As a result, strategic documents end up declaring necessary actions like ensuring, increasing, creating, forming, updating, implementing, improving, attracting, and developing without any quantitative targets.

In this context, several issues arise for researchers and managers during the strategizing process. Specifically, these include justifying the development goals of a specific system (management sphere), understanding the necessary sequence of decisions regarding changes to its parameters, and ensuring that decisions are supported by the necessary resources within the specified time of transformation. Unfortunately, the analysed publications do not provide any recommendations regarding the determination of quantitative parameters, the rationale for selecting specific indicators or goal-measuring metrics, their planned values, absolute and relative increases, urgency, and the sequence of achievement, or their boundary values. Modern methods of econometric modelling are also not used.

In contrast to the authors’ previous studies focused on the quantitative assessment of both external and internal threats to national energy security, this new research stands out in the following ways: first, by considering the “hydrogen” indicator (as one of the new priorities outlined in Ukraine’s energy strategy until 2050); second, by adjusting the boundary values due to the military actions of the rf; and third, by focusing on the study of strategizing methods.

The new technology for strategizing a sustainable future proposed in this study involves two approaches: structural evolution and projected structural transformation, reflected in the following operational modes: structural evolution, and projected structural transformation (balanced sustainable development and rapid targeted transformation). An important achievement of the research is identifying the mechanism for regulating the speed of structural change in the object of study.

Thus, it becomes crucial to develop new scientific approaches to strategizing a sustainable future. In contrast to classical forecasting methods (based on the principle *“the past determines the future”*) and classical foresighting (*identifying long-term factors and trends*), a new approach to strategizing is proposed based on the principle *“the trajectory towards a future determines the future”* through identifying the current state, constructing desired development trajectories toward defined goals in the security dimension, and decomposing integral indices using adaptive regulation methods from control theory. The approach we propose can be called **scientific and strategic foresighting.**

The article **aims** to continue developing a model to analyse a specific area of management in the security dimension and methods of strategizing its development – scientific and strategic foresighting – to develop strategic scenarios for post-war recovery, using the example of Ukraine’s energy security.

2. Literature review

In their previous works, Kharazishvili et al. [1] explored the application of a systems approach to describe national “energy security,” specifically arguing the necessity of forming a set of indicators that can be used to describe energy security. In particular, they proposed identifying a complex of indicators describing the energy security sector and grouping them by specific components describing the “system”: elements, functions, structure, materials, etc. [1].

When describing the energy security sector, important questions arise regarding the list of indicators. Typically, the following groups are employed to describe the list of energy security indicators: economic, political, technological, ecological, and social. Sovacool and Brown [2], Azzuni and Breyer [3], and Cherp and Jewell [4] highlight other aspects, such as managerial, social, innovation, security, political, and geopolitical. The most common approach is the “4 A’s” – availability, accessibility, affordability, acceptability – which was most fully developed by the Institute of Energy Economics of Japan [5].

In the case of a very simplified list of indicators, there is a risk of overlooking important aspects. With a large number of indicators (>50 or even over 100), the “curse of dimensionality” problem arises. As there are no established rules for their formation, the proposed list reflects the authors’ perspective. Moreover, other issues related to statistical data in different countries necessitate developing and coordinating statistical services. Therefore, the list of indicators and their grouping may change for improvement and refinement to match various countries, specific needs, and priorities.

The current dynamics of technological development in the production and consumption of energy resources, the transformation of energy market models, change of sources and routes of supply, and the use of energy potential by some countries as an instrument of political influence require revision of approaches to analyzing the energy security and scientific substantiation of strategic scenarios of security development. In contrast to the state of *security*, which implies readiness for threats of a certain level, ensuring *sustainability* requires constant adaptation of the object of management to changes in the security environment due to the continual presence of threats of various natures and origins, both internal and external to such an object. This distinction between security and sustainability only emphasises the multifaceted nature of these concepts, e.g. in statics (state, level of security) and dynamics (preservation of the desired parameters of the state’s functioning and/or the projected trajectory of its sustainable development).

Therefore, the realisation of sustainable development goals in its security dimension is consistent with the goals of ensuring the energy sustainability of any state [6–10], aim to maintain a sustainable environment in light of growing industrialisation [11]. The importance of this sustainable development goal is undeniable in terms of the energy deficit caused by different factors of energy insecurity [12,13], including the riskiest factors caused by world energy uncertainty, financial development, and technological advancement [14]. In Ukraine, an exemplifying country for this research, ensuring energy security based on reliable foresighting is extremely important due to the need for energy sector transformations [15]. After the war, Ukraine should change the structure and functioning models of the country's economy and energy sector. For this reason, the practices of energy security regulation and geopolitical risks consideration highlighted in previous research [16] are valuable for designing the energy security policy. Particularly, regional development policy and government support for technological development require significant changes and renovation. In this regard, the development of new methodological approaches to science-based strategizing of spatial associations is of great relevance. Its successful implementation in energy policy development can be further scaled for other countries where the energy transformation requires reliable foresight

A well-known tool for studying the future is **classical forecasting**, which is a quantitative characterization of the future based on past data and analysis of long-term factors and development trends. There are concomitantly several reasons that complicate macroeconomic **forecasting** [1,17–19]: the possibility of unforeseen changes and the impact of exogenous parameters cannot be ruled out; forecasting is always based on preliminary information that will become more accurate only over time; the objective complexity of the forecasting task due to the nonlinearity of economic processes, the presence of corruption and the shadow economy, the instability of weather conditions caused by global climate change and their impact on the agricultural sector of the economy, the dependence of the economy on external and internal threats; the methodological problem of choosing forecasting models.

Among the variety of ideas in macroeconomic modelling theory, there are two main areas. The first one is based on dynamic models of rational behaviour of a typical economic entity in an efficient market, which forms rational expectations under conditions of general uncertainty. The second area of macroeconomic modelling is based on a systematic approach to analyzing macroeconomic dynamics. In this case, the nonlinearity of economic processes is considered fundamental.

The first approach is the use of statistical analysis and the construction of regression (linear and nonlinear) equations to model economic variables of individual markets based on historical data with further extrapolation of macroeconomic indicators (vector autoregressive models, multivariate models, regression methods and systems of simultaneous equations; lagged distribution models, etc.) [20–23]. This approach is successfully tested in comparative economic complexity and energy security analysis in high-income and middle-income countries [24,25]. The most well-known macromodels used in developed countries, especially in the US, are the vector auto regression (VAR) model, the vector error correction model (VECM), and the Klein macro models [26]. They all reflect neo-Keynesian or neoclassical approaches. The basic principle of these models is: "*The past determines the future*".

The second approach is the simulation modelling of socio-economic processes under consideration of the analytical dependencies of economic properties using modern economic theories with the methods of economic cybernetics [27–29]. Kharazishvili [1] identified distinctive features of the second approach:

- "…the proposed models are mainly deterministic rather than statistical, which immediately eliminates several problems: the presence of long dynamic data series, statistical estimation of parameters, errors associated with parameter averaging;
- a successful combination of Keynesian, classical, and monetarist approaches within a single model, which enhances the economic significance and fundamental nature of the developed approaches;
- the definition of aggregate demand and aggregate supply not as scalar values, but as functions of the general price level – the GDP deflator, which makes it possible to determine the general macroeconomic equilibrium through their interaction, as well as the subsequent emergence of many new functionalities" (p. 7).

The information above leads to several conclusions:

- classical forecasting always contains an inherent pathology of errors;
- the use of the principle of classical forecasting "the past determines the future" does not work in a transformational economy - the future is not a continuation of the past but takes on fundamentally different forms and structures. In other words, the structure of the object of study, the interaction between components, and the target parameters of such interaction will be different in the future;
- forecasting does not answer the question: what should be the parameters of the desired state of the object of management. The target parameters of the object of management are determined not only by past trends but primarily by the management entity's understanding of the goals of the object's development;
- since both above approaches use input data based on classical forecasting methods, they are practically applicable only for the short term - a year or two (questionable).

Another main tool for solving these tasks is **foresight**, which, according to the United Nations Industrial Development Organization (UNIDO), is a system of methods for expert evaluation of strategic projects of socio-economic and innovative development, identification of technological breakthroughs, and the ability to determine the impact on the economy and society in the medium and long term [30]. American researcher Ben Martin provided another good formulation, defining **foresight** as systematic attempts to assess the long-term prospects of science, technology, economy, and society to identify strategic research directions and new technologies that can bring the greatest socio-economic benefits [31]. The application of foresight has gradually changed from technological, market-oriented [32,33] to socio-economic [34–36] and strategic [37–42], i.e. integrated into the system of strategic management of a certain object.

On the other hand, **foresight** is characterized as a process, i.e. **foresighting**: "…a process involving systematic attempts to look into the long-term future of science, technology, economics, and society in order to identify areas of strategic research and the emergence of general technologies that are likely to bring the greatest economic and social benefits" ([43], p. 96).

Thus, considering the publications above, *foresighting* is not a method, but a technology that incorporates methods developed in various scientific fields, i.e. work on forecasting the desired, not any future, e.g.: Delphi method; identification of critical technologies; scenario development; expert panels; SWOT analysis; economic and mathematical modelling; brainstorming; regression analysis; extrapolation; simulation modelling; neural networks, multi-criteria analysis, etc. In contrast to *forecasting*, which is the determination of medium- and long-term forecasts for the development of the national economy, the task of *foresighting* is to identify long-term factors and trends, i.e. qualitative rather than quantitative results.

At the same time, both strategic foresight and long-term forecasting are intended primarily to determine what can happen, not what should be done. Thus, the tools of economic and mathematical modelling, underlying classical foresight and classical forecasting, are not perfect and have not only advantages but also significant disadvantages.

In mathematical terms, the use of *foresighting* is a necessary but not sufficient condition. That is why most of the strategies developed in Ukraine are declarative in nature without scientific substantiation of strategic guidelines through the declaration of necessary measures such as: *ensuring, promoting, creating, forming, updating, implementing, improving, attracting, developing*.

Unfortunately, expert assessments are full of subjectivity and do not exclude fundamental errors. The use of the SWOT-analysis method can be considered necessary for determining strategic directions of development, but not sufficient to substantiate quantitative strategic assessments of the future state. Classical forecasting methods based on correlation and regression analysis are considered inappropriate here. Firstly, forecasting gives a continuation of existing trends into the future, which is not always fulfilled; secondly, it always contains an error; thirdly, it is necessary to know how the components and indicators of sustainable development should change to achieve the desired state of development. Considering these peculiarities, strategic planning for such an extremely important area of economic development requires completely different approaches.

3. Methods

To develop strategic scenarios for the post-war revival of energy security, the concept of sustainable development in the security dimension [44] is used "…as a management construct containing a general systemic view of the ways of transition from the current position of the object of management to the desired one" within the framework of a secure existence. The theoretical basis of the concept is applied systems theory, management theory, economic cybernetics, statistical analysis, artificial intelligence methods (cluster analysis) embracing three stages: *identification, scientific substantiation of institutional measures, and strategizing.*

The methodological foundations for identifying and strategizing national security components outlined below are applicable at any level of decision-making (country, region, type of economic activity – industry, rail transport, air transport, agriculture, enterprise, etc.) and concerning individual components of national security (energy security, environmental, information, economic, social, informational, etc.).

Strategizing is the final element of sustainable development concept in the security dimension, which is impossible without the **identification** stage: determining the boundaries of safe existence [45–47]; integral assessment of the level of sustainable development: multiplicative form of the integral index, combined normalization method, dynamic weighting coefficients, simultaneous integral convolution of indicators and their boundary values [44,48].

Each listed point contains scientific novelty, confirmed by copyright certificates for the work, which allows for new findings when applied. For example, the determination of the boundaries of the safe existence of dynamic systems is based on applied systems theory [47], specifically the concept of the extended "homeostatic plateau" (Fig. 1) [49], which allows for the justification of safety gradations: critical, threshold, optimal in both directions of the plateau, related to the areas of positive, neutral, and negative feedback.

Quantitative values of safety gradations are linked to the extension of the "*t*-test" method through the construction of probability density functions, the calculation of the vector of boundary values for the most characteristic types of distribution of the "exemplary" sample: normal, log-normal, and exponential (Table 1).

Since all processes in the economy are nonlinear, a nonlinear form of integral indices is used. In this study, normalisation of indicators is performed using a combined method that eliminates the shortcomings of normalisation methods based on reference values and the range of variation. At the same time, the "sliding matrix" method is applied to determine dynamic weighting coefficients instead of constant ones and expert assessments.

Table 1
A formalized vector of threshold values.

Type of Indicator Probability Density Function	Lower Threshold	Lower Optimal Value	Upper Optimal Value	Upper Threshold
Normal	$\mu - t \times \sigma$	$\mu - \sigma$	$\mu + \sigma$	$\mu + t \times \sigma$
Lognormal (tail right)	$\mu - t \times \sigma / k_{as}$	$\mu - \sigma / k_{as}$	$\mu + \sigma$	$\mu + t \times \sigma$
Lognormal (tail left)	$\mu - t \times \sigma$	$\mu - \sigma$	$\mu + \sigma / k_{as}$	$\mu + t \times \sigma / k_{as}$
Exponential (tail right)	$\mu - \sigma / k_{as}$	μ	$\mu + \sigma$	$\mu + t \times \sigma$
Exponential (tail left)	$\mu - t \times \sigma$	$\mu - \sigma$	μ	$\mu + \sigma / k_{as}$

Scientific substantiation of institutional measures is the development of institutional measures to overcome threats to sustainable development by modelling the main priority strategic directions that cover almost all sustainable development indicators. Kharazishvili et al. [48] discussed the development of an expert-mathematical method for assessing the impact of threats on the level of national energy security for its adaptation along the trajectory of sustainable development. This method combines expert assessments regarding the change in the components of the integral index and formalised mathematical calculations of their impact on the integral index and indicators. Since any classification of threats is somewhat conditional and subjective, two types of threats were considered:

- threats that are internal elements of the security object are indicators;
- threats that cannot be described by indicators of the state of the security object are external to the security object and require other approaches to consider their impact on the level of energy security.

The research findings are to identify national regulatory measures capable of changing energy security indicators in a way that would implement or restore the desired trajectory of sustainable development.

Strategizing covers the following stages: goal-setting – defining strategic goals; building a future trajectory of the desired development;

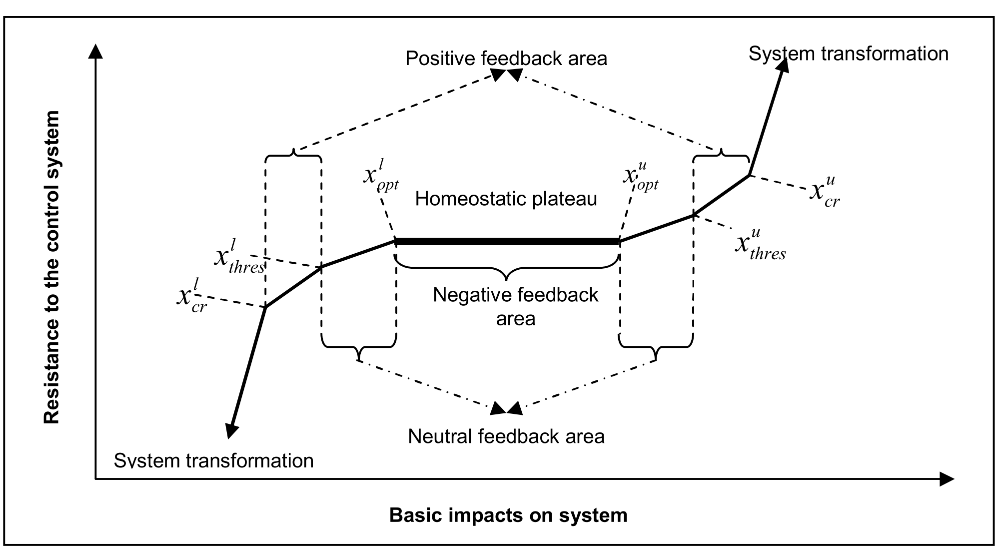


Fig. 1. Extended homeostatic plateau of the dynamical system [44,48].

synthesis of strategic guidelines of components and indicators of the security object through the decomposition of integral indices using adaptive control methods (Fig. 2) [44] derived from the theory of management [50]; implementation of the “denormalisation” procedure, which is transition from dimensionless indicators to macro indicators in natural units of measurement.

The approach used to strategize sustainable development differs significantly from classical forecasting methods (due to the principle of forecasting “the past determines the future”) and classical foresight (identification of long-term factors and trends), which a priori contain an **inherent pathology of errors**. The new approach is based on the principle that “the trajectory towards a future determines the future” by building desired development trajectories towards certain goals in the security dimension and solving the inverse problem by decomposing integral indices using adaptive control methods from management theory (see Fig. 2) to synthesise the dynamics of macroeconomic indicators, that is, it reflects the technology of scientific and strategic foresighting. A comparative table of approaches and results to strategizing (Table 2) vividly reflects the advantages of scientific and strategic foresight over classical forecasting and foresighting.

Thus, the aim of strategizing is not only to determine the desired state of the object but also to define a course there and make the necessary changes in time on the way to the desired goal [51–53]. This approach a priori determines the knowledge of yearly integral indices I_t through the construction of the desired development trajectory towards the set goals, which allows for being used as reference valuesI_t^{targ} in the adaptive regulation model (Fig. 2). In the block “Identification of the level of development”, the equations of the integral convolution of the components from (3) with their weighting coefficients averaged $n+1$ over the past years are used in turn, where n- is the number of components or indicators.

The task of the control device is to determine such a change in the normalized indicators$z_{i,t}$ that reduces the control criterion F_t (square of the error) to zero. Changes in the indicators are calculated by gradient methods, considering the constraints. “…Since F is an ordinary function of the parameters x_i, a necessary condition for the existence of a relative extremum is that the partial derivatives of this function for all variables must simultaneously be equal to zero:

$$\nabla F = grad\,F = \left(\frac{\partial F}{\partial x_i}\right) = 0. \tag{1}$$

Since the control parameters xi are subject to restrictions that determine the physical or given limit of their possible change, when they reach the maximum values corresponding to the sign of the gradient for a given variable, these parameters are fixed at the specified maximum values. At the same time, the search for the minimum F is carried out for other variables at fixed sliding boundary values of some variables until the sign of the gradient changes. The solution to the problem obtained in the presence of the imposed constraints is not optimal, but suboptimal, because some gradient vector components may not equal zero” [44]. It is the consideration of the limitations of changes in components or

Table 2
Comparative characteristics of approaches to strategizing.

Strategy based on the principle of “**the past determines the future**”	Strategy based on the principle of “**the future is determined by the trajectory to the future**”
“Foresighting” is “…the process of systematically attempting to look into the long-term future of science, technology, economics and society in order to identify areas of strategic research and the emergence of common technologies that can bring the greatest economic and social benefits” (Cuhls K)	**Scientific and strategic foresight** is determination of goals and trajectory of their achievement, decomposition of integral indices of the future trajectory to synthesize the necessary values of components and their indicators to find the integral index within the desired development trajectory
Foresight and forecasting methods:	**Strategizing methods**:
- Delphi method; - identification of critical technologies; - scenario development; expert panels; - SWOT analysis; - economic and mathematical modelling; - brainstorming; - regression analysis; - extrapolation; - simulation modelling; - neural networks; - multicriteria analysis, etc.	- building integral indices in the security dimension (identification); - goal-setting means defining strategic goals for a given perspective in security coordinates; - building a future trajectory of targeted development; - synthesis of strategic guidelines of components and indicators of the security object through the decomposition of integral indices using adaptive control methods from the theory of management (strategizing); - implementation of the procedure of “denormalisation” - transition from dimensionless indicators to macro indicators in natural units of measurement.
The result of forecasting is a quantitative characterization of the future based on extrapolation of past data and analysis of long-term factors and development trends	
The result of foresighting is the identification of long-term factors and trends, rather than the construction of long-term forecasts of the national economy; the emphasis is on qualitative rather than quantitative results	**The result of strategizing** is quantitative science-based dynamics of components, indicators and macroeconomic indicators that ensure the desired trajectory of the national economy in the medium and long term (strategic plan)

Compiled by authors.

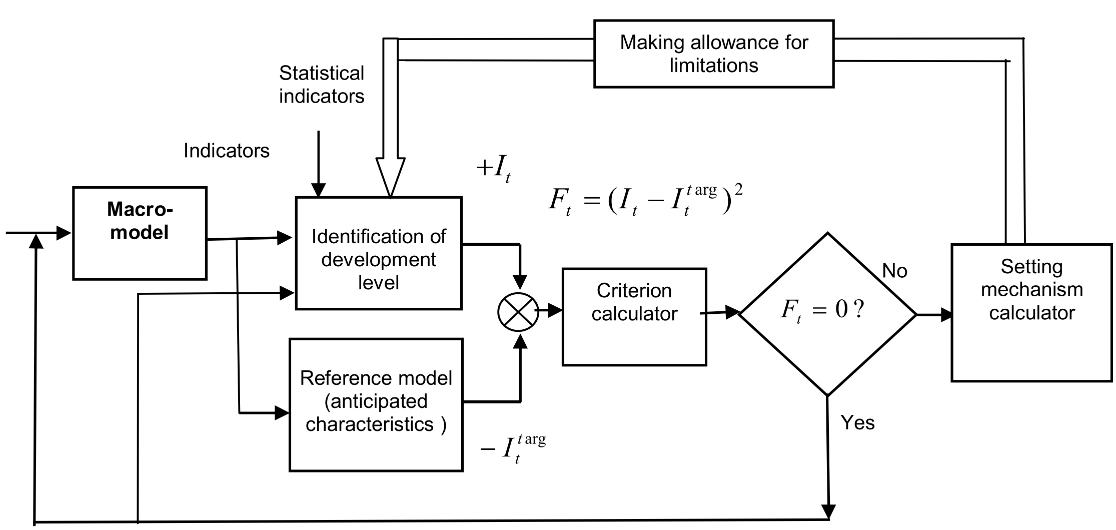


Fig. 2. Generalized scheme of adaptive control system with a reference model [44,48].

indicators that gradually changes the structure of energy security every year.

This is a classic case of applying an adaptive regulation scheme, where a trajectory is built, and constraints are set for the overall integral index, which, through its decomposition, leads to determining the dynamics of its components according to the existing structure through weighting coefficients. If we apply the construction of desired trajectories not for the overall integral index, but for the integral indices of its components with corresponding constraints and sustainable development goals, we accelerate the structural transformation of the object of study. This automatically ensures balanced sustainable development at the level of all components of the integral index, except for their indicators, for which some imbalances may theoretically persist.

This case is appropriate when the integral index value is near or on the verge of the lower optimal value. In this case, the structure of energy security (or any other component of national security) will change slowly, ensuring the calculation of dynamic weighting coefficients that take into account the impact of all indicators.

Consequently, due to the constraints, condition (1) is no longer necessary for the existence of an extremum, so this problem belongs to the class of mathematical programming problems – nonlinear parametric optimisation.

This leads to the **elements of scientific novelty** in the proposed technology of scientific and strategic foresighting:

– ***structural evolution mode***, which involves building desired trajectories toward defined goals for the overall integral index and its subsequent decomposition into components, and then to indicators using adaptive regulation methods from control theory;
– ***mode of projected structural transformation*:**
  (a) *at the level of components of the integral index* – **balanced sustainable development:** This involves constructing desired trajectories to defined goals (lower optimal, middle optimal, or upper optimal in the vector of boundary values) for each component of the integral index, integral evaluation of the components and their boundary values for a defined period to obtain the overall integral index, and decomposing all components for synthesizing strategic values of indicators;
  (b) *at the level of indicators of all components* – **rapid targeted transformation:** This involves the subject setting the target structure and parameters of individual indicators for the desired future, performing an integrated convolution from the current state to the specified year of indicators for all components and their boundary values, and then convolving the components to obtain the dynamics of the overall integral index. Moreover, the trajectory of indicator changes can be defined as a linear or nonlinear function up to the specified year;
– **mechanism for regulating the speed** of structural change in the object of study toward the level of sustainable development by regulating the magnitude of constraints of integral indices during their decomposition using adaptive regulation methods, their components, and indicators.

Scientific and strategic foresighting is a universal approach that provides for the preservation of the system structure in the absence of violation of the constraints of components and indicators (evolutionary development), its slow adaptation to the challenges of achieving the target state when approaching the constraints (adaptive development) and active adaptation to the target state (purposeful development) when they are exceeded. In this case, the entity projects the target level of the integrated energy security index (or integral indices of its components) and determines the trajectory of its achievement; and then determines, through a sequential decomposition, the necessary dynamics of changes in the values of certain components and then indicators while maintaining or slowly and actively changing their structure when approaching and exceeding the limits.

Each indicator, component, or integral index is characterised by a vector of boundary values: the upper/lower optimal, threshold, and critical one. If the goal is set as sustainable development, meaning the achievement of the integral index of the security object at the centre of the homeostatic plateau – the middle optimal value, the constraints can be the upper critical, threshold, or optimal values. Furthermore, if, during the decomposition of the integral indices, the values of components or indicators exceed the optimal and threshold values, they are fixed at those levels until the gradient values change sign. Therefore, ensuring the specified level of the integral index is achieved by adjusting other components or indicators, forcing them to “catch up” to ensure the optimization criterion (the square of the error approaches zero). Thus, the closer the constraints are to the specified goal, the more indicators achieve their goal, which means the acceleration of the structural transformation of the object under study.

The scientific findings were obtained through data processing in the software *Strategizing*, which implements the adaptive control scheme (Fig. 2) in the *C*++ programming language.

Table 3 presents the structure of the input data and the results of the program’s operation.

Each file of input data provides the following:

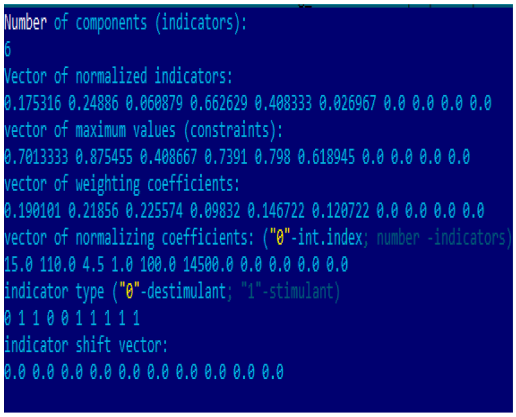
- Number of components (indicators): The program automatically generates a multiplicative convolution for the specified number of indicators;
- Vector of normalized indicators: Used as the last known point for the next trajectory of sustainable development;
- Vector of maximum values (constraints): Used as a regulator to accelerate the structural change of the object under study;
- Vector of weighting coefficients: Characterizes the influence of each component in the last known point of the integral index and is used for subsequent periods;
- Vector of normalizing coefficients: (“0″-integral index; number - for indicators): used to perform the “denormalization” procedure after synthesis, i.e., converting dimensionless indicators into indicators with natural units of measurement;
- Indicator type (“0″-de-stimulant; "1″-stimulant): Used to select the formulas for denormalization;
- Indicator shift vector: Used when there are negative indicator values and determines the magnitude of the shift in the indicator’s values and its boundary values by an amount greater than 5 % of the maximum negative value, with subsequent consideration for returning to the natural state.

In the resulting fragment of the program’s work in ‘Strategizing’, the initial and target values of the integral index are shown, along with strategic indicators: the initial and final normalized values of all indicators. The next line presents the values of strategic indicators in natural units of measurement and the achieved value of the integral index.

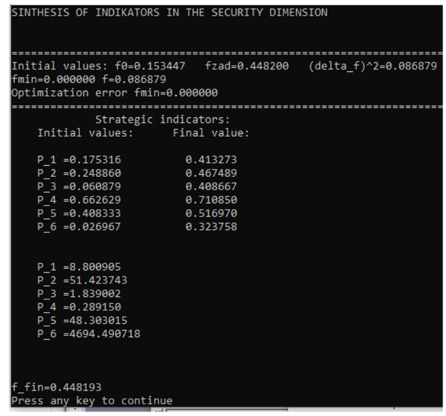
Based on data about the number of indicators, the computer program automatically generates the required multiplicative form of the integral index, which is applied in calculations. The adaptability of the indicator value adjustment is achieved by using an optimal gradient method, selecting the optimisation step based on the Newton-Raphson method, and quadratic approximation at the final stage, which implements the function of multi-parameter nonlinear optimisation with consideration of constraints.

The system of energy security indicators is defined by 47 indicators, the number of which is necessary and sufficient for a complete description of the system, taking into account the trade-off between completeness and complexity and their belonging to stimulators *S* or destimulators *D*. The energy security indicators were formed based on the principles of systematics, comprehensiveness, hierarchical organisation, adequacy, clarity, continuity, and accessibility, reflecting the integrity of the system of indicators. In other words, the inherent impossibility of

Table 3
A fragment of the input data file and calculation results screen.



```
Number of components (indicators):
6
Vector of normalized indicators:
0.175316 0.24886 0.060879 0.662629 0.408333 0.026967 0.0 0.0 0.0 0.0
vector of maximum values (constraints):
0.7013333 0.875455 0.408667 0.7391 0.798 0.618945 0.0 0.0 0.0 0.0
vector of weighting coefficients:
0.190101 0.21856 0.225574 0.09832 0.146722 0.120722 0.0 0.0 0.0 0.0
vector of normalizing coefficients: ("0"-int.index; number -indicators)
15.0 110.0 4.5 1.0 100.0 14500.0 0.0 0.0 0.0 0.0
indicator type ("0"-destimulant; "1"-stimulant)
0 1 1 0 0 1 1 1 1 1
indicator shift vector:
0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0
```



```
SINTHESIS OF INDIKATORS IN THE SECURITY DIMENSION

=====================================================================
Initial values: f0=0.153447   fzad=0.448200   (delta_f)^2=0.086879
fmin=0.000000 f=0.086879
Optimization error fmin=0.000000
=====================================================================
           Strategic indicators:
    Initial values:      Final value:

    P_1 =0.175316         0.413273
    P_2 =0.248860         0.467489
    P_3 =0.060879         0.408667
    P_4 =0.662629         0.710850
    P_5 =0.408333         0.516970
    P_6 =0.026967         0.323758


    P_1 =8.800905
    P_2 =51.423743
    P_3 =1.839002
    P_4 =0.289150
    P_5 =48.303015
    P_6 =4694.490718


f_fin=0.448193
Press any key to continue
```

reducing the properties of the system of indicators to the sum of the properties of its components and the impossibility of deriving the properties of the whole from those of the parts was taken into account. Overall, a system is understood as a set of interconnected elements that interact and form a whole – i.e., a system [54].

A distinctive feature of the proposed list of energy security indicators (Appendix 1) is the inclusion of "shadow" indicators and 9 other indicators not calculated by national statistical authorities. Without considering these, the assessment of energy security would not reflect the actual situation, as substantiated by Kharazishvili et al. [55] and Kharazishvili et al. [48].

The identified indicators are grouped into components according to the Energy Security Strategy of Ukraine [56]: resource sufficiency (I), economic affordability (II), economic efficiency (III), energy efficiency (IV), environmental acceptability (V), sustainability of functioning (VI), protection of national interests (VII).

In calculating the boundary values of indicators, the values of energy indicators from developed countries over the past 5–10 years were used as an "exemplary" sample, which can be considered a model for the country under study. The countries selected for this research in various combinations were Japan, Germany, Belgium, France, Finland, Sweden, Switzerland, Italy, Spain, Turkey, The Netherlands, Portugal, and Poland.

Using the formulas for boundary values according to the type of distribution [55] and the computer program Auto Thresholds, we obtain vectors of boundary values for all indicators. Their integral convolution provides the integral boundary values of the components of energy security (Table 4) necessary for further strategizing.

Table 4
Vectors of limit values of energy security components of Ukraine*.

Components of sustainable development/thresholds	*Critical upper/ lower*	*Threshold upper/lower*	*Optimal upper/lower*	*2022*
Resource sufficiency	0,1067 / 0,8585	0,2248 / 0,6459	0,3588/ 0,5141	0,3195
Economic affordability	0,1279 / 0,9251	0,2877 / 0,8299	0,4422 / 0,6649	0,3338
Economic efficiency	0,2512 /0,9695	0,3593 / 0,8667	0,4868 / 0,6693	0,2097
Energy efficiency	0,1427 / 0,8748	0,3375 / 0,8099	0,5109 / 0,6877	0,2057
Environmental acceptability	0,1016 / 0,8767	0,2719 / 0,7497	0,4416 / 0,6188	0,2668
Sustainability of functioning	0,2295 / 0,9571	0,4437 / 0,8988	0,6720 / 0,8207	0,3926
Protection of national interests	0,3632 / 0,9871	0,5275 / 0,8721	0,6666 / 0,7913	0,3128
Institutional and organizational support	0,4196 / 0,9864	0,5697 / 0,8517	0,6647 / 0,7957	0,4574
Quality of policy implementation	0,3196 / 0,9876	0,4874 / 0,8907	0,6684 / 0,7873	0,2167
Integral index	**0,1678 / 0,9187**	**0,3316 / 0,8011**	**0,4917 / 0,6664**	**0,2932**

* Model calculations by the authors.

4. Findings

The authors have developed a universal technology for strategizing sustainable development of any national security component, which, in contrast to classical forecasting methods (based on the principle *"the past determines the future"*) and classical foresighting (determining long-term factors and trends), is based on the principle *"the trajectory towards a future determines the future"* through the construction of desired development trajectories toward defined goals in the security dimension. This involves solving the reverse problem by decomposing integral indices using adaptive regulation methods from control theory to synthesise the dynamics of strategic indicators and macro-indicators, which can be considered *scientific and strategic foresighting*.

The proposed technology of scientific and strategic foresighting allows implementing the following strategizing modes: structural evolution, projected structural transformation: (modes of balanced sustainable development and rapid targeted transformation). Additionally, as elements of scientific novelty, there has been identified a mechanism for regulating the speed of structural restructuring of the object under study through changing constraints from the boundary value vector and a mechanism for achieving the level of balanced sustainable development through building desired trajectories of the components of the integral index. Thus, the integral convolution of these components will a priori ensure the level of sustainable development for the overall integral index and its components, while the result of decomposing these trajectories will be the dynamics of indicators that ensure the achievement of the defined goals.

The strategic dynamics of components, indicators, and macro-indicators for a specified timeframe essentially form a strategic plan for post-war development. Unlike traditional approaches to classical forecasting and foresighting, which provide an approximate answer to "***what might happen***," the modern approaches to strategizing provide an answer to "***how it should be done***."

The strategic vision of sustainable development first involves determining how far, from the point of sustainable development, the overall integrated index, the integrated indices of its components, and the indicators themselves are, which is the basis of the goal-setting stage. In other words, it is first necessary to determine the starting point from which to start moving towards sustainable development. For this purpose, it is necessary to determine the criterion of sustainable development to formulate the necessary goals.

The inability to formulate strategizing goals in a scientifically sound manner confirms the idea that goal-setting is associated with societal issues. Goal-setting is not within the scope of economic science and cannot be distilled into a prescriptive set of guidelines [57]. Obviously, realising goals may be controversial and require compromise solutions, but this refers to the realisation, not the setting of goals.

It is the development of the concept of an extended "homeostatic plateau" (Fig. 1) ([44], pp. 66–72) that made it possible to scientifically substantiate the gradations of safety (critical, threshold, optimal) associated with the areas of positive, neutral and negative feedback in both directions of the plateau, and their quantitative values with the extension of the "*t*-test" method by calculating the statistical characteristics of the "exemplary" sample, building the probability function and solving the problem of recognizing patterns of an arbitrary sample by artificial intelligence methods with the subsequent calculation of the vector of threshold values. At the same time, the criterion of sustainable development can be considered the average optimal value of the "homeostatic plateau", where there are the best conditions for the system's functioning and negative feedback. Thus, 30 years after Alle's quote about the impossibility of scientific substantiation of the goal-setting stage, the applied systems theory, statistical analysis, and artificial intelligence methods become the theoretical basis for determining the goal-setting stage.

The advantages of scientific and strategic foresighting will be demonstrated using the example of Ukraine's energy security. Unlike previous works by Sukhodolia et al. [54] and Kharazishvili et al. [48], which were dedicated to studying the quantitative assessment of the impact of both external and internal threats on the level of national energy security, the new study differs in the following ways: first, it includes the "hydrogen" indicator (as one of the new priorities outlined in Ukraine's energy strategy for the period up to 2050); second, it involves adjusting the boundary values due to the ongoing military actions by rf; and third, the focus of the study is on researching strategic planning methods.

According to the defined components of energy security and the methodology for identifying the current state of sustainable development, a mathematical model was obtained in the following form ([54] p. 36; [48]) (2):

level strategizing for two approaches of scientific and strategic foresight: ***structural evolution*** (evolutionary) and ***projected structural transformation*** (transformational), which both use the principle "*the trajectory towards a future determines the future*":

Consistent implementation of the integral convolutions of indicators and components of energy security (2) simultaneously with the convolution of the corresponding thresholds allows for identifying the level of sustainable development of Ukraine's energy system in the security dimension (Fig. 3).

Given the starting point of strategizing and the integral security gradations, we choose strategic goals for a certain period - the end of 2030; and build exponential trajectories for their achievement. Concomitantly, we know a priori what the integral energy security index is (should be) equal to each year.

The development scenarios in the field of energy security are based on the choice of an energy supply model for the needs of society and people, which provide three fundamentally different options for achieving the future state of energy security:

1. *The model of evolutionary development*, where *the methods and structure of energy production and energy use are preserved* as target parameters. At the same time, at the initial stage, the restoration of the destroyed energy infrastructure of Ukraine *is carried out on the existing technological base*, with further evolutionary replacement of technological equipment with new or modernised equipment with a low level of capital investment.
2. *The "green transition" model*, where the parameters reflecting *the priority use of renewable energy sources* are selected as target parameters. In this case, priority is given to the restoration and further expansion of the share of renewable energy sources in the energy balance. Outdated technologies (coal-fired generation) are gradually being replaced, but a high level of centralized management and high-capacity generating facilities is maintained.
3. *A model of the sustainability of energy supply to consumers* in the event of a crisis, where the parameters reflecting *the priority of generating capacities dispersal, diversification of supply routes and development of smart local energy supply systems* are selected as targets. Concomitantly, the restoration and further development of the country's energy sector is based on the principle of guaranteeing the provision of vital services (energy supply to consumers and infrastructure that provides vital services/functions).

$$\begin{cases} I_{I-VII} = \prod_{k=1}^{7} I_{k,\,t}; \quad P_{i,j} = \prod_{j=1}^{6} P_{i,j}^{b_{i,j}}; \quad P_{i,j} = \left[P_{krit,ij}^{low}; P_{thres,ij}^{low}; P_{opt,ij}^{low}; P_{opt,ij}^{apper}; P_{thres,ij}^{apper}; P_{krit,ij}^{apper}\right]; \\ I_{I,t} = \prod_{i=1}^{10} z_{i,j}^{a_t}; I_{II,t} = \prod_{i=1}^{5} z_{i,j}^{a_t}; I_{III,t} = \prod_{i=1}^{6} z_{i,j}^{a_t}; I_{IV,t} = \prod_{i=1}^{6} z_{i,j}^{a_t}; I_{V,t} = \prod_{i=1}^{5} z_{i,j}^{a_t}; I_{VI,t} = \prod_{i=1}^{5} z_{i,j}^{a_t}; I_{VII,t} = \prod_{i=1}^{2} z_{i,j}^{a_t}; \\ I_{VII-I,t} = \prod_{i=1}^{5} z_{i,j}^{a_t}; I_{VII-2,t} = \prod_{i=1}^{6} z_{i,j}^{a_t}; \end{cases} \tag{2}$$

where *k* is the number of components; *I* is the number of indicators; *j* is the number of safety gradations.

Given that the Ukrainian government restricted access to information about the country's fuel and energy complex (FEC), experts determined the values of several indicators for 2021–2022. It can be agreed that although all forecasts are highly speculative today, they are necessary to understand the depth of the decline and to justify the indicators and macroeconomic indicators of Ukraine's post-war economic recovery policy. To demonstrate the advantages of the developed strategizing methodology, the article compares the results of energy security

The proposed models of energy supply for the needs of society and humans become the basis for scenario modelling, namely:

Inertial (*Scenario 1*) - the target value of the integral index is to reach the lower threshold value of the integral index, which will represent the implementation of the evolutionary development model.

Adaptive (*Scenario 2*) - the target value of the integral index is to reach the average value between the lower threshold and the lower optimal values, which will be based on the implementation of the green transition model with the slow adaptive evolution of the energy sector.

Target (*Scenario 3*) - the target value of the integral index is to achieve the lower optimal value, which will reflect the targeted

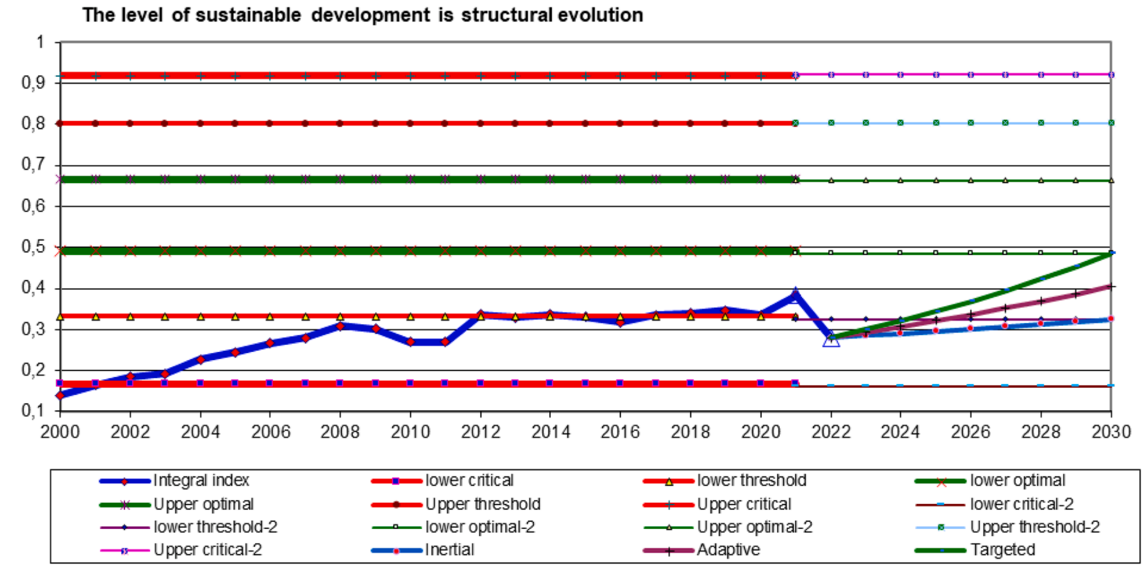


Fig. 3. Dynamics of the integrated energy security index on the trajectory of sustainable development with strategic goals to the "structural evolution" approach.

implementation of the model of sustainable energy supply to consumers.

Substituting the values of the integral index into the "*reference model*" (Fig. 2), we will obtain the dynamics of energy security components that ensure the achievement of the targets defined. The decomposition of the integral index is carried out first for the components (Fig. 4), and then for the indicators, considering the determined dynamic weighting coefficients at the end of the identification period – year 2022 (the reverse task). The resulting dynamics of components and indicators is, in fact, a strategic plan for the post-war revival of Ukraine's energy security.

The approach of "***The designed structural transformation***" involves solving the "direct" problem through the integral convolution of the indicators of each component, followed by the integral convolution of the components to obtain the overall integral index (Fig. 5).

Moreover, for each indicator, target values by 2030 or 2050 are set, which are used in the Energy Strategy of Ukraine [56] as expert estimates, taking into account the defined vector of limit values of each indicator. The dynamics of changes in the indicators by 2030 or 2050 are calculated as a linear function of time, i.e., by 2030, we get the dynamics of changes in all energy security indicators based on the officially approved values by 2050.

The obtained dynamics of the integrated index components make it possible to determine the dynamics of the integrated energy security index by solving a direct problem (Fig. 6).

Comparison of the two approaches to sustainable development strategy. The "*structural evolution*" approach uses an exponential trajectory of the integral index (this determines the exponential trajectory of components and indicators) and constant weighting coefficients for future periods (because when solving the inverse decomposition problem, we do not know the values of indicators), calculated for the final identification period. Meanwhile, the distribution of the required increase in the integral indices of the components and their indicators is carried out depending on the weighting factors, which causes a gradual evolutionary (slow and active) change in the structure of energy security (the contribution of each component and indicator) depending on the approach and exceeding of the relevant limits (see Fig. 4).

The main feature of the "*structural evolution*" approach to strategy is that we know what value the integral index (a generalized representation of the goal) of energy security should have for a certain perspective and consistently synthesize the necessary dynamics of components and indicators (determine the change in the system structure) by solving the inverse problem, i.e., decomposition of integral indices: from the integral index to the indices of components and dynamics of indicators.

To strategize according to the "*Projected Structural Transformation*" approach (at the level of indicators), dynamic weighting coefficients are calculated for each period, taking into account the obtained linear dynamics of indicator changes, which leads to a faster-forced change in the energy security structure due to the rapid change in indicators and their weighting coefficients. However, the existing combination of indicators does not always allow calculating dynamic weighting coefficients by the principal components method when all indicators are significant, which increases the minimum required matrix size for calculating dynamic weighting coefficients, making them constant over a significant range and in some cases gives artificial nonlinear dynamics of components (see Figs. 5, 6).

According to the *Projected Structural Transformation* approach, the main feature of strategizing is that we know the target values of the indicators (the target changes in the system structure), but we do not know the final values of the components and the integral index as a whole (a generalised representation of the desired goal).

Let's reveal the differences in achieving the final results of the two approaches to strategizing by the dynamics of the integrated energy security index for the period up to 2030 (Fig. 7).

The situation is completely different with the second mode, "Designed structural transformation" – *balanced sustainable development*, which can be chosen for any defined goal. Desired trajectories (usually exponential) for achieving specified goals (e.g., the middle optimal value of the boundary value vector) are built for each component of the integral index. Therefore, we know the final values of the integral indices of the components, can determine the dynamic weighting coefficients, and perform the convolution to obtain the dynamics of the overall integral index, which a priori will equal the middle optimal value. The synthesis of the dynamics of the indicators for each component is determined through the decomposition of the integral indices of the components with known weighting coefficients for the last period of identification of each component throughout the entire study period. However, there is a possibility of indicator imbalances, meaning varying deviations from the point of sustainable development, which can be eliminated by changing the constraints.

Thus, the researcher can choose which method of strategizing is most suitable for solving their task. Simulation results demonstrate the advantage of "balanced sustainable development" for the target scenario "A model of the sustainability of energy supply to consumers" among the three strategizing modes (Fig. 8).

The calculations for the "scientific and strategic foresight" approach

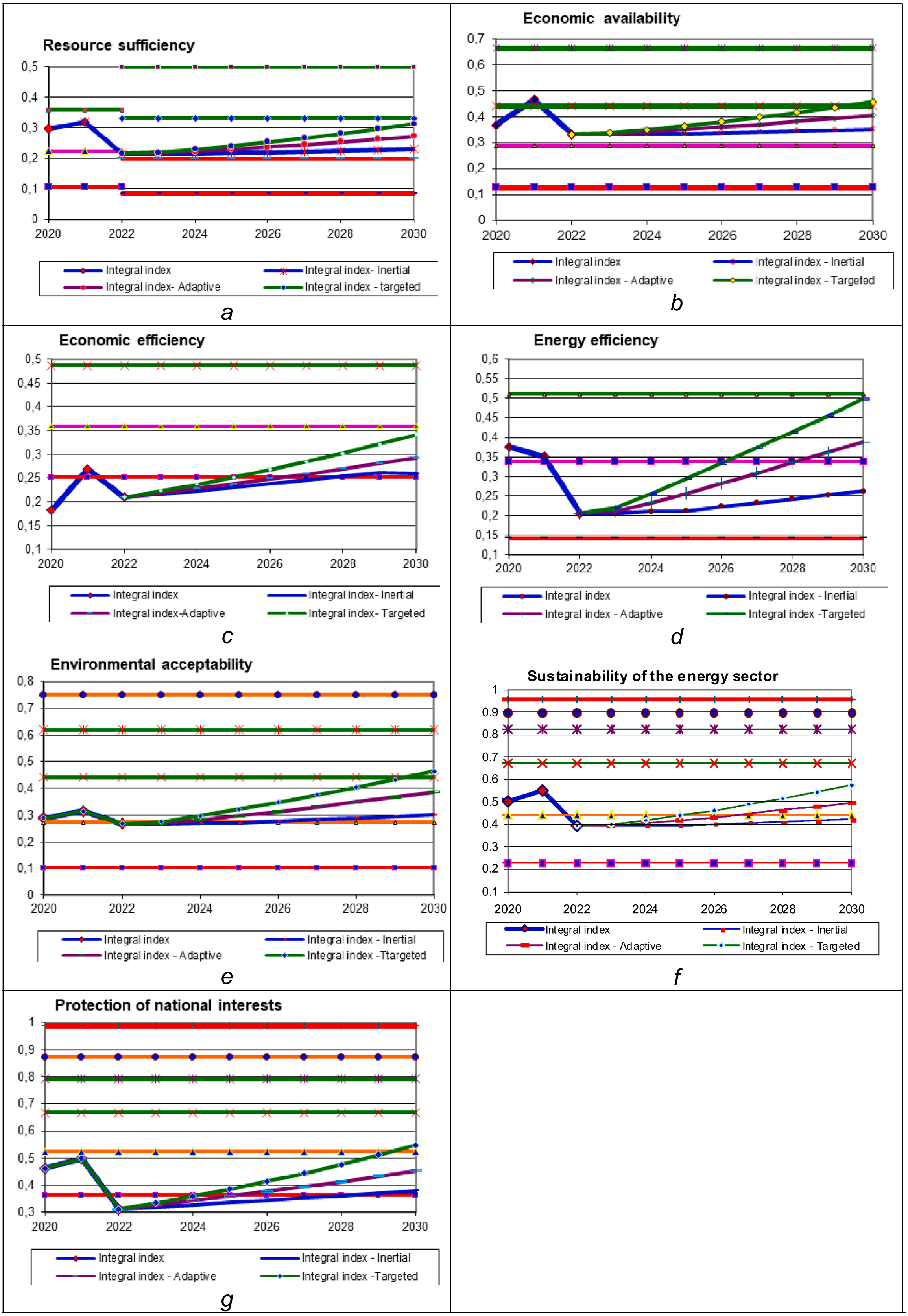


Fig. 4. Strategic dynamics of integral indices of energy security components according to the "structural evolution" approach.

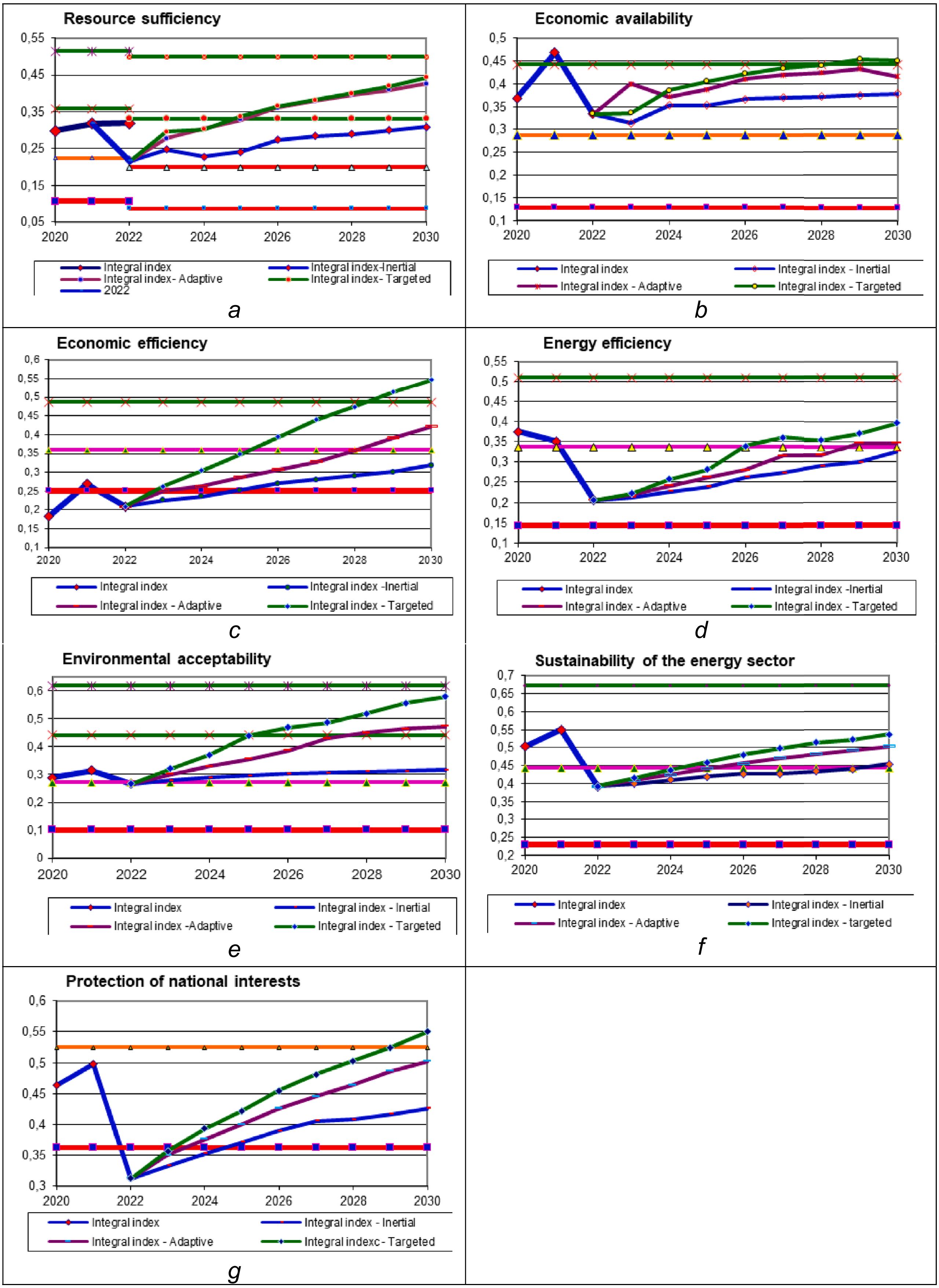


Fig. 5. Strategic dynamics of integral indices of energy security components according to the "Designed structural transformation" approach.

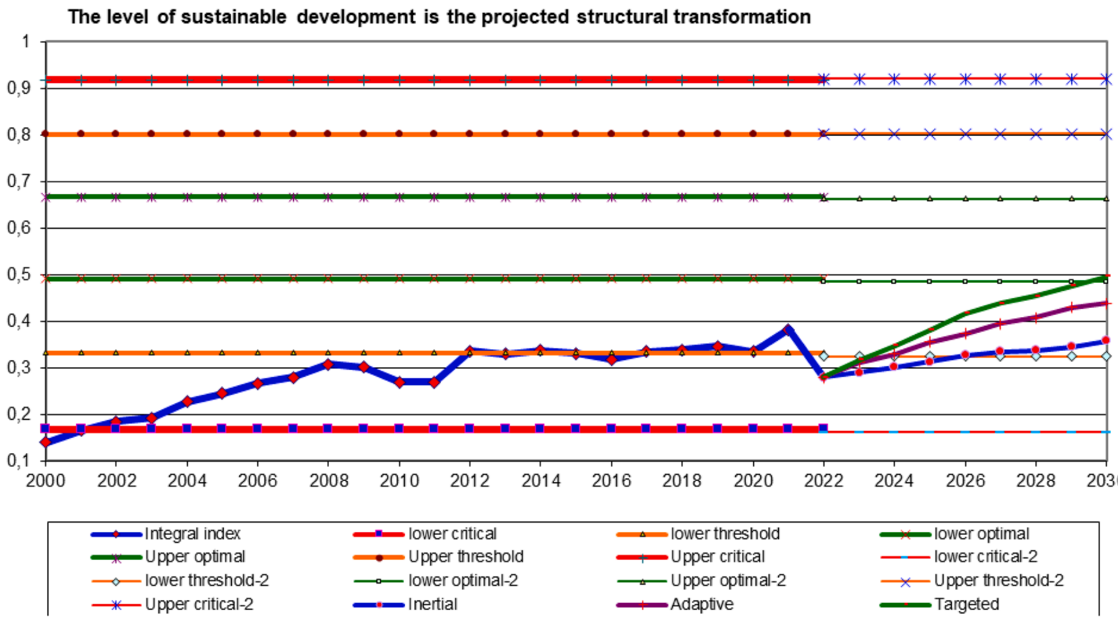


Fig. 6. Strategic dynamics of the integral index of energy security according to the "Designed structural transformation" approach.

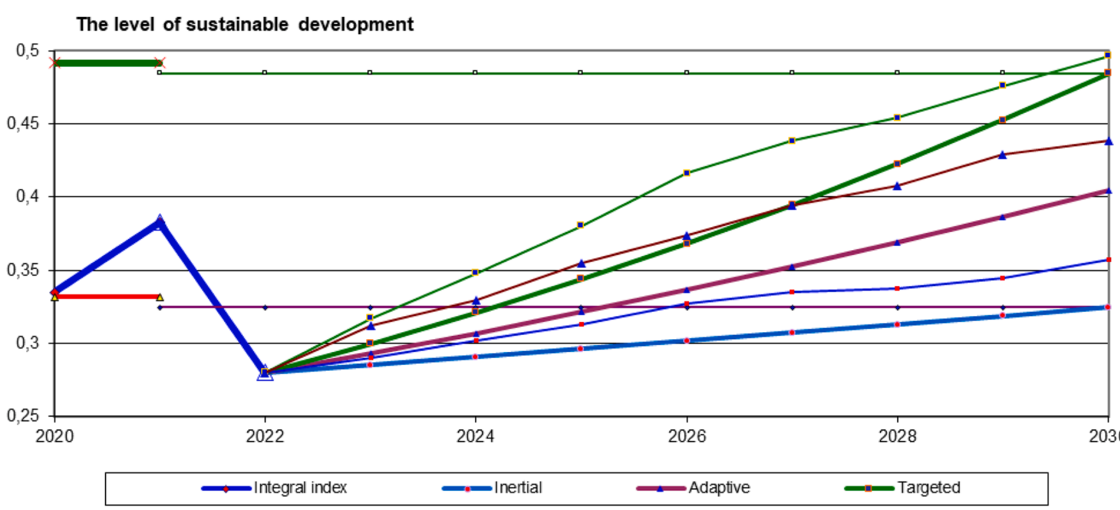


Fig. 7. Dynamics of the integrated index of energy security according to two approaches: in bold – "structural evolution"; in fine print – "Designed structural transformation".

to strategizing were made for the "upper optimal" constraint gradation. Setting the "average optimal" or "lower optimal" constraints as gradations will allow for a faster increase in the structural reorganisation of the security facility, depending on the practical feasibility of the calculated scenarios. This makes it possible to regulate the speed of structural reconstruction of the security object, i.e., the control property.

5. Discussion and conclusions

Unlike the authors' previous works [48,54], which focused on the quantitative assessment of the impact of both external and internal threats on the level of national energy security, the new research differs in the following aspects: firstly, it includes the "hydrogen" indicator (as one of the new priorities identified in Ukraine's energy strategy up to 2050); secondly, it adjusts the boundary values due to the ongoing military actions by Russia; and thirdly, the focus of the research is on examining strategic planning methods.

Strategizing is based on the results of identifying the current level of sustainable development in the security dimension and is a logical continuation of it. The authors developed an identification methodology that differs in the scientific novelty of the system of energy security indicators, the determination of safe existence boundaries (security gradations and their quantitative values), the multiplicative form of the integral index, the combined normalization method, dynamic weighting coefficients, and simultaneous integral convolution of both the indicators and their boundary values. This approach allows the determination of the level of security or risk on a single scale.

Modern approaches to integral assessment, particularly one of the most well-known and authoritative ones [58], have certain gaps: the lack of a scientific definition for weighting coefficients (expert-based determination or all are considered equal); the artificial determination of security gradations (innovation leaders, strong innovators, moderate innovators, modest innovators) instead of scientifically justified grading for assessment. At the same time, the authors of the methodology themselves acknowledge the impossibility of comparing calculation results for each year [58], which is a significant flaw in the evaluation

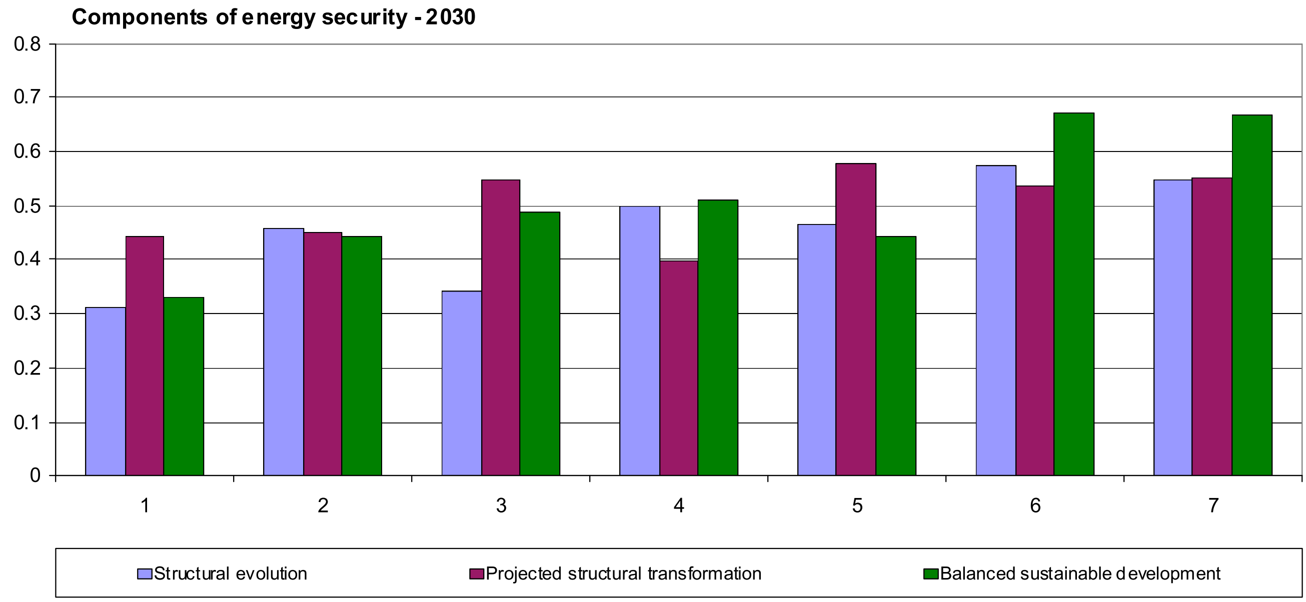


Fig. 8. The value of energy security components at the end of 2030 for the target scenario according to three approaches to strategizing: *1 – Resource sufficiency; 2 – Economic availability*; 3 – Economic efficiency; 4 – Energy efficiency; 5 – Environmental acceptability; 6 – Stability of functioning; 7 – Protection of national interests.

methodology. Such an approach does not align with the principles of scientific strategizing and leads followers of these approaches back to using correlation-regression analysis (the past determines the future). While these approaches are well-tested and actively used for forecasting energy security, they have certain methodological differences, such as the use of vector autoregressive models [20], quantile regression [21,24,25] or the most advanced econometric modelling [14], the general logic of application remains common. The review of existing approaches to strategizing energy security and other components of national security showed the imperfection of approaches that do not provide clear, specific guidelines for action planning - quantitative strategic benchmarks of components, indicators, and macroeconomic indicators, monitoring of which would allow controlling the process of achieving strategic goals. Previously proposed approaches do not use modern methods of economic and mathematical modelling to determine the quantitative parameters of development strategies, to justify the feasibility of choosing certain indicators, such as measures of goals, their planned values, absolute and relative growth, urgency and priority of achievement.

Both classical forecasting and classical foresight, as tools for predicting the future, use the same methods: the Delphi method, identification of critical technologies; scenario development; expert panels; SWOT analysis; economic and mathematical modelling, brainstorming, regression analysis, extrapolation, simulation modelling, neural networks, multi-criteria analysis, etc. The basis of these methods is the principle that "*the past determines the future*" or expert assessments, which do not exclude principled errors; the future is not a continuation of the past but takes on fundamentally different forms and structures, especially in a transformational economy.

The most common mistake researchers make in strategizing is forecasting the integral index of the studied object based on past periods using polynomials. This approach ("*blind*" mathematisation) to forecasting the level of security diminishes the economic essence of such a complex concept as sustainable development or security and discredits the very principle of econometric modelling. A weak justification for this is the fact that the coefficient of determination is close to "1", and other criteria are considered acceptable.

Thus, **forecasting results in a quantitative prediction of the future based on extrapolation of past data and analysis of long-term factors and development trends; foresight results in the identification of long-term factors and trends** rather than the construction of long-term forecasts of the national economy; the emphasis is on qualitative rather than quantitative results.

To address the identified shortcomings, **Scientific and Strategic Foresighting** as a fundamentally new approach is proposed, based on the principle "*the trajectory towards a future determines the future*." In contrast to classical forecasting and foresighting methods, Scientific and Strategic Foresighting is based on applied systems theory, management theory, economic cybernetics, statistical analysis, and artificial intelligence methods (pattern recognition).

This approach provides a systemic view of the current level of the energy component of sustainable development in the security dimension and allows for scientifically substantiated strategic development scenarios. The content of the scenarios includes the quantitative dynamics of all components and indicators of sustainable development leading to the desired year, the implementation of which will enable the achievement of defined goals. In other words, instead of a classic forecast (***what may happen***), we propose a systemic identification of the level of sustainable development and a scientifically justified strategic development plan (***how it should be done***).

5.1. Main findings

The proposed scientific and strategic foresighting technology directly relies on the scientific justification of the boundaries for the safe existence of dynamic systems [49,59], which makes it possible to consider the achievement of indicators and integral indices at the average value of the "homeostatic plateau" as the **criterion for sustainable development**. This plateau is determined by a pair of optimal values (upper and lower) of the boundary value vector, where the best conditions for the system's functioning and negative feedback exist. Therefore, the simultaneous integral folding of indicators and their boundary values allows for determining the level of safety/unsafety, the scientific justification for **setting goals** for the given perspective, and the strategic scenarios for developing the research object.

The scientific novelty of the proposed scientific and strategic foresighting technology lies in the following:

1. The application of an adaptive regulation model from control theory for the following modes of operation**:**
   - ***structural evolution*** mode**, which** involves constructing desired trajectories to defined goals for the overall integral index and its successive decomposition into components, and then into indicators using adaptive regulation methods from control theory;
   - mode of ***projected structural transformation*:**
     (a) *at the level of* the *components of the integral index* – **balanced sustainable development**: this involves constructing desired trajectories to defined goals (lower optimal, middle optimal, or upper optimal of the boundary value vector) for each component of the integral index, integral assessment of the components and their boundary values for a given perspective to obtain the overall integral index, decomposition of all components for synthesising strategic values of indicators;
     (b) *at the level of indicators of all components* – **rapid targeted transformation**, which means that the subject sets the target structure and parameters of individual indicators for the desired perspective, performs simultaneous integral folding from the current state to the designated year for indicators of all components and their boundary values and then folds the components to obtain the dynamics of the overall integral index. Moreover, the trajectory of changes in indicators can be defined as a linear or nonlinear function to the designated year.
2. **The proposal of a mechanism for regulating the speed** of structural change of the object of research to the level of sustainable development through regulating the values of boundary constraints of integral indices during their decomposition using adaptive regulation methods, their components, and indicators.
3. **The development and proposal of three scenarios for the energy sector of Ukraine**'s post-war period based on different modes of functioning of scientific and strategic foresighting, considering the energy supply model, which provides three fundamentally different options for achieving the future state of energy security: the *evolutionary development* model, the *green transition* model, and the *resilience of energy supply to consumers*. The final result of the strategizing was the scientific justification of the dynamics of components and indicators, ensuring which will guarantee the achievement of the defined goals.

5.2. Practical implications

To demonstrate the results of scientific and strategic foresighting, specifically the modes of its operation, energy supply models for societal and human needs were selected, which provide three fundamentally different options for achieving the future state of energy security: the "*evolutionary development model*" (inertial scenario), the "*green transition model*" (adaptive scenario), and the "*resilience of energy conservation for consumers* model" (targeted scenario) (see Fig. 8).

Thus, we have the following characteristics of the two approaches of **Scientific and Strategic Foresight**:

- "*Evolutionary* approach" prevails over the "transformational" approach in terms of the following components: economic affordability; energy efficiency; sustainability of the energy sector; it is almost equal to the "transformational" approach in terms of protecting national interests.
- "*Transformational* approach" (at the level of indicators) outweighs the "evolutionary approach" in terms of the following components: resource sufficiency, economic efficiency, environmental acceptability; practically equals the "evolutionary" approach in terms of protecting national interests.

As can be seen from the modelling results, strategizing according to the "transformational" approach requires a more aggressive change in the dynamics of the integrated energy security index than strategizing according to the "evolutionary" approach. This is due to the fact that the requirement to change the structure and parameters of the indicators causes the system to resist changes, and in order to achieve the desired results within a certain range of system development planning, additional efforts are needed (more influential decisions, faster implementation of decisions).

To compare with the evolutionary and transformational approaches, Fig. 8 shows the result of strategic management using transformational approaches at the level of components – *balanced sustainable development* for the same defined goal – achieving the lower optimal value of integral indices for all components. The modelling results clearly demonstrate the advantage of this mode in terms of the total growth of components (structural evolution – 3.199; projected structural transformation – 3.5; balanced sustainable development – 3.552). Balanced sustainable development also requires significant aggressive changes, so it is advisable to use it when the integral indices approach the lower optimal value or to extend the strategic planning horizon.

An example of the system's resistance to rapid changes could be the maintenance of the subsidy system for a wide range of consumers in Ukraine's energy markets. Another example is the slow pace of development of local energy supply systems and renewable energy at the direct consumer level. Periodic attempts by the Ukrainian government to replace subsidies with market regulation mechanisms led to political pressure, sometimes even resulting in the government's resignation. At the same time, the relatively rapid development of large renewable energy installations in Ukraine (primarily solar power plants) during the 2011–2021 period was driven by significant economic incentives provided by the government, such as the introduction of "green" tariffs.

A distinctive feature of this study is the scientific substantiation of the goal-setting stage, as opposed to the statement that it is impossible to scientifically substantiate goal-setting because it is not within the scope of economic science and science in general.

Researchers and managers gain an additional tool for analysis and justification of management decisions when creating a strategy for the development of a specific management area.

In practical terms, the developed method allows to:

- implement a project-based approach to forming the goals of strategic development in specific management areas, developing various strategic planning scenarios, which is especially important when these areas are undergoing significant transformations or are in a crisis state;
- compare approaches to the development strategy of a management area, assess the advantages and disadvantages of different policies, and determine the necessary resources and time parameters for implementing management decisions to achieve the goals.

Considering the known shortcomings and comments to the existing approaches of integral assessment, and most importantly, to the approaches of strategizing, the results obtained are of practical importance for an adequate and scientifically based identification of the level of sustainable development in the security dimension for any component of the national security of any country. Much more important are the results of scientifically based determination of strategic scenarios of sustainable development, which, instead of qualitative long-term forecasts based on the principle of classical forecasting such as "*the past determines the future*", allow obtaining a scientifically based answer to the question: what should be the dynamics of components, indicators and macroeconomic indicators of national security components to achieve predetermined goals. The task of the policy is to use all possible levers to comply with the determined dynamics of macroeconomic indicators.

Limitations and future directions

For Ukraine, whose energy sector has suffered significant destruction during the war, this is especially important. The energy development goals can politically be defined in different ways: either preserving the pre-war structure of generating capacities and the energy balance structure (energy mix) or forming a fundamentally new energy structure.

The use of new energy technologies, expanding the share of renewable energy in the energy balance, transforming regulatory mechanisms in energy markets, and integrating Ukraine into new regional markets will completely transform not only the energy structure as an element of the system but also the interaction between the system's elements. The future of Ukraine's energy sector must be projected without relying on previous dynamics of indicators.

Regarding the limitations of the methods and tools used for strategic planning: From the perspective of ease of application, in order of listing: *structural evolution* (weighting coefficients of the most recent period), *balanced sustainable development* (dynamic weighting coefficients for determining the dynamics of the overall integral index, weighting coefficients of the most recent period for synthesizing indicators; it is advisable to use this approach when integral indices approach the lower optimal value of the boundary vector), and *projected structural transformation at the level of indicators* (dynamic weighting coefficients for integral folding of components and the overall integral index). However, the existing combination of indicators does not always allow calculating dynamic weighting coefficients by the principal components method when all indicators are significant, which increases the minimum required matrix size for calculating dynamic weighting coefficients, making them constant over a significant range and in some cases gives artificial nonlinear dynamics of components.

Scientific and strategic foresighting is a universal approach that is not tied to any specific domain, such as energy, ecology, economic security, or social spheres. This characteristic makes it a versatile method. On the contrary, any specific domain is linked to the security gradations of this approach, where defining the limits of the integral index, its components, and indicators plays an important role.

Considering the known shortcomings and criticisms of existing integral assessment approaches, and most importantly, of strategic planning approaches, the results obtained have practical significance for adequate and scientifically grounded identification of sustainable development levels in the security dimension for any component of national security.

Moreover, the theoretical and conceptual aspects of the work, as well as the development of working software for individual stages of the technology, represent an important step towards creating an **A**utomated **S**ystem for **I**dentification and **S**trategic **P**lanning (**ASISP**) of sustainable development for components of national security.

CRediT authorship contribution statement

Yurii Kharazishvili: Writing – original draft. **Yuriy Bilan:** Writing – original draft. **Oleksandr Sukhodolia:** Writing – original draft. **Olena Grishnova:** Writing – original draft. **Halyna Mishchuk:** Writing – original draft.

Declaration of competing interest

We wish to submit an original research article entitled "Scientific and strategic foresight of Ukraine's energy security: the trajectory of sustainable development" for consideration by Sustainable Futures. We confirm that this work is original and has not been published elsewhere, nor is it currently under consideration for publication elsewhere. Thank you for your consideration of this manuscript.

Appendix

Appendix 1
Energy security indicators for Ukraine.

No.	Indicator (*I*)	Type	Dimension
I. *Resource sufficiency*			
1	Meeting needs with own primary energy resources	*S*	% of consumption
2	Cost of import of energy resources	*D*	% of GDP
3	Share of the resource in the energy balance: oil and petroleum products	*D*	% in balance
4	natural gas	*D*	% in balance
5	thermal coal	*D*	% in balance
6	nuclear and thermonuclear energy	*S*	% in balance
7	hydropower	*S*	% in balance
8	solar and wind energy	*S*	% in balance
9	biomass energy	*S*	% in balance
10	hydrogen	(S)	% in balance
II. *Economic affordability*			
11	Cost of consumed energy resources for the state	*D*	% of GDP
12	Annual electricity consumption per person	*S*	Mwh
13	Annual energy consumption per person	*S*	toe
14	Share of household income used for housing and related services	*D*	%
15	Quality of supply of primary resources, fuel and energy	*S*	% (expert assessment)
III. *Economic efficiency*			
16	Gross domestic product per person	*S*	thousand US dollars.
17	Level of investment by enterprises of the fuel and energy complex	*S*	% of fuel and energy complex production
18	Level of renewal of fixed assets of the fuel and energy complex	*S*	% of the fixed assets of the fuel and energy complex
19	Shadowing of the fuel and energy complex	*D*	% of Gross value added of the fuel and energy complex
20	Labor remuneration in the fuel and energy complex	*S*	% of fuel and energy complex production
21	Concentration of energy markets according to the Herfindahl-Hirschman index	*D*	Index (by suppliers)
IV. *Energy efficiency*			
22	Energy intensity of gross domestic product	*D*	toe/1000 US dollars
23	Energy share in gross domestic product	*D*	% of Gross value added of the fuel and energy complex in GDP
24	Shadow consumption of primary energy resources	*D*	% of GDP
25	Share of consumption for energy needs	*D*	%, total supply

(*continued on next page*)

Appendix 1 (*continued*)

No.	Indicator (*I*)	Type	Dimension
26	Losses in heat supply networks	*D*	%, transmission volume
27	Losses in power grids	*D*	%, transmission volume
V. *Environmental acceptability*			
28	Level of CO_2 emissions per TPES	*D*	t CO_2/toe
29	Level of CO_2 emissions per unit of GDP	*D*	kg/US dollars
30	Final carbon intensity of energy	*D*	g CO_2/MJ
31	Share of CO_2 emissions from electricity and heat generation plants	*D*	%, total emissions
32	Share of renewable energy in final consumption	*S*	%, final consumption
VI. *Sustainability of functioning*			
33	Share of the largest supplier in imports (by type of primary energy resources)	*D*	%
34	Level of technological dependence of imports/exports from a single source (by types of energy technology)	*D*	% (expert assessment)
35	Volume of stocks/reserves by types of primary energy resources	*S*	monthly consumption
36	System Average Interruption Duration Index (SAIDI)	*D*	minutes/year
37	Efficiency and effectiveness of response to crisis situations	*S*	% (expert assessment)
VII. *Protection of national interests*			
	Institutional and organizational support:		
38	production processes and infrastructure	S	% (expert assessment)
39	management processes and infrastructure	S	% (expert assessment)
40	support and service processes and infrastructure	S	% (expert assessment)
41	processes and infrastructure for maintaining facilities at all stages of the life cycle	S	% (expert assessment)
42	Information and communication processes and infrastructure	S	% (expert assessment)
	Quality of policy implementation:		
43	Level of involvement in EU energy markets	*S*	% (expert assessment)
44	Level of shadow capital utilization in the fuel and energy complex (extractive industry, electricity, gas and water production)	*D*	% of official
45	Quality of government policy	*S*	% (expert assessment)
46	Quality of human resources (technical and managerial)	*S*	% (expert assessment)
47	Relevance of political leaders to the challenges faced by the system	S	% (expert assessment)

Source: developed by the authors based on [55,48] and available official data from the State Statistics Service of Ukraine, model and expert estimates.

Data availability

No data was used for the research described in the article.

References

[1] Y.M. Kharazishvili, *Teoretychni Osnovy Systemnoho Modeliuvannia Sotsialnoekonomichnoho Rozvytku Ukrainy: monohrafiia*, [Theoretical Foundations of System Modelling of Socio-Economic Development of Ukraine: a Monograph], TOV “Polihraph-Konsaltynh”, Kyiv, 2007, p. 324 *(in Ukrainian)*.

[2] B. Sovacool, M. Brown, Competing dimensions of energy security: an international perspective, Annu. Rev. Environ. Resour. 35 (1) (2010) 77–110.

[3] A. Azzuni, C. Breyer, Definitions and dimensions of energy security: a literature review, Wiley Interdiscip. Rev. Energy Environ. 7 (1) (2018) e268, https://doi.org/10.1002/wene.268.

[4] A. Cherp, J. Jewell, The concept of energy security: beyond the four as, Energy Policy 75 (2014) 415–421, https://doi.org/10.1016/j.enpol.2014.09.005.

[5] APERC, Asia Pacific energy research centre. A Quest for Energy Security in the 21st Century: Resources and Constraints, Institute of Energy Economics, Japan, 2007, pp. 1–113.

[6] M.F. Bashir, Y. Pan, M. Shahbaz, S. Ghosh, How energy transition and environmental innovation ensure environmental sustainability? Contextual evidence from top-10 manufacturing countries, Renew. Energy 204 (2023) 697–709.

[7] P.T. Dat, H.T. Hung, Determinants of sustainable development: a case study in Vietnam, Montenegrin J. Econ. 19 (2) (2023) 97–107, https://doi.org/10.14254/1800-5845/2023.19-2.8.

[8] M. Murshed, S. Khan, A.A. Rahman, Roadmap for achieving energy sustainability in Sub-Saharan Africa: the mediating role of energy use efficiency, Energy Rep. 8 (2022) 4535–4552.

[9] A. Pandey, M. Asif, Assessment of energy and environmental sustainability in South Asia in the perspective of the sustainable development goals, Renew. Sustain. Energy Rev. 165 (2022) 112492.

[10] M. Svazas, V. Navickas, R. Paskevicius, Y. Bilan, L. Vasa, Renewable energy versus energy security: the impact of innovation on the economy, Rynek Energii 1 (2023) 60–71.

[11] B. Doğan, M. Shahbaz, M.F. Bashir, S. Abbas, S. Ghosh, Formulating energy security strategies for a sustainable environment: evidence from the newly industrialized economies, Renew. Sustain. Energy Rev. 184 (2023) 113551, https://doi.org/10.1016/j.rser.2023.113551. Get rights and content.

[12] H. Mishchuk, J.J. Czarkowski, A. Neverkovets, E. Lukács, Ensuring sustainable development in light of pandemic “new normal” influence, Sustainability 15 (18) (2023) 13979, https://doi.org/10.3390/su151813979.

[13] D. Streimikiene, Energy supply security in Baltic States, Montenegrin J. Econ. 19 (3) (2023) 125–135, https://doi.org/10.14254/1800-5845/2023.19-3.14.

[14] J. Wang, S. Ghosh, O.A. Olayinka, B. Doğan, M.I. Shah, K. Zhong, Achieving energy security amidst the world uncertainty in newly industrialized economies: the role of technological advancement, Energy 261 (2022) 125265, https://doi.org/10.1016/j.energy.2022.125265.

[15] O. Boiko, R. Biały, T. Pruchnik, A. Szurlej, Transformation of the Ukrainian energy sector, Rynek Energii 2024 (4) (2021) 9–15.

[16] K. Lin, S. Ghosh, S. Abbas, M. Shahbaz, D. Ferraz, B. Doğan, Heterogenous impact of energy security and environmental regulations on energy transition: exploring the disparity between high-income and middle-income countries, Renew. Energy 237 (2024) 121610, https://doi.org/10.1016/j.renene.2024.121610.

[17] M.P. Clements, D.F. Hendry, Forecasting in macro-economics. Time Series Models, Chapman and Hall/CRC, 2020, pp. 101–142.

[18] P.M. Maçaira, A.M.T. Thomé, F.L.C. Oliveira, A.L.C Ferrer, Time series analysis with explanatory variables: a systematic literature review, Environ. Model. Softw. 107 (2018) 199–209.

[19] H. Mishchuk, H. Yurchyk, Y. Bilan, Shadow incomes and real inequality within the framework of leadership and social change. Leadership For the Future Sustainable Development of Business and Education, Springer, Cham, 2018, pp. 89–101, https://doi.org/10.1007/978-3-319-74216-8_10.

[20] A. Carriero, T.E. Clark, M. Marcellino, Capturing macro-economic tail risks with Bayesian vector autoregressions, J. Money Credit Bank 56 (5) (2024) 1099–1127.

[21] I. Dawar, A. Dutta, E. Bouri, T. Saeed, Crude oil prices and clean energy stock indices: lagged and asymmetric effects with quantile regression, Renew. Energy 163 (2021) 288–299.

[22] I. Iwasaki, X. Ma, S. Mizobata, Board structure in emerging markets: a simultaneous equation modeling, J. Econ. Bus. 128 (2024) 106160.

[23] M. Tanaka, N. Bloom, J.M. David, M. Koga, Firm performance and macro forecast accuracy, J. Monet. Econ. 114 (2020) 26–41.

[24] L.K. Chu, S. Ghosh, B. Doğan, N.H. Nguyen, M. Shahbaz, Energy security as new determinant of renewable energy: the role of economic complexity in top energy users, Energy 263 (2023) 125799, https://doi.org/10.1016/j.energy.2022.125799.

[25] J.E. Payne, H.H.D. Truong, L.K. Chu, B. Doğan, S. Ghosh, The effect of economic complexity and energy security on measures of energy efficiency: evidence from panel quantile analysis, Energy Policy 177 (2023) 113547, https://doi.org/10.1016/j.enpol.2023.113547.

[26] L. Klein, Comparative Performance of U. S. Econometric models, Oxford University Press, 1991.

[27] P. Bordalo, N. Gennaioli, A. Shleifer, Overreaction and diagnostic expectations in macroeconomics, J. Econ. Perspect. 36 (3) (2022) 223–244.

[28] O. Cepni, I.E. Guney, N.R. Swanson, Forecasting and nowcasting emerging market GDP growth rates: the role of latent global economic policy uncertainty and macroeconomic data surprise factors, J. Forecast. 39 (1) (2020) 18–36.

[29] V. Wieland, M.H. Wolters, The diversity of forecasts from macroeconomic models of the US economy, Econ. Theory 47 (2011) 247–292.

[30] S. Kryukov, Foresight: the forecast for the formation of the future, Terra Econom. 8 (3) (2010) 7–11, part 2.

[31] B. Martin, Technology Foresight in a Rapidly Globalizing Economy, SPRU. *Science and Technology Policy Research*, University of Sussex, 1995.
[32] T.M. Antony, G. Suresh, Determinants of credit risk: empirical evidence from Indian commercial banks, Banks Bank Syst. 18 (2) (2023) 88–100, https://doi.org/10.21511/bbs.18(2).2023.08.
[33] W. Jongadsayakul, Determinants of the successful single stock futures market in Thailand, Invest. Manag. Financ. Innov. 19 (2) (2022) 274–284, https://doi.org/10.21511/imfi.19(2).2022.24.
[34] M. Bosovska, M. Boiko, L. Bovsh, A. Okhrimenko, N. Vedmid, Foresight (prevision) of development of the tourist system in Ukraine, Probl. Perspect. Manag. 21 (4) (2023) 696–712, https://doi.org/10.21511/ppm.21(4).2023.52.
[35] I. Didenko, K. Valaskova, A. Artyukhov, S. Lyeonov, L. Vasa, Quality of scientific activity as a determinant of socio-economic development, Econ. Sociol. 15 (3) (2022) 301–318, https://doi.org/10.14254/2071-789X.2022/15-3/17.
[36] V.G. Manalu, S. Nurhayati, R.P. Setyanto, The moderating effect of competitive intensity on foresight capability and product innovation of SMEs in Indonesia, Probl. Perspect. Manag. 21 (1) (2023) 219–229, https://doi.org/10.21511/ppm.21(1).2023.19.
[37] C.N. Cook, S. Inayatullah, M.A. Burgman, W.J. Sutherland, B.A. Wintle, Strategic foresight: how planning for the unpredictable can improve environmental decision-making, Trends Ecol. Evol. (Amst.) 29 (3) (2014) 531–541, https://doi.org/10.1016/j.tree.2014.07.005.
[38] European Commission (2020). Strategic foresight report. Retrieved 3 May 2021, from https://ec.europa.eu/info/strategy/strategic-planning/strategic-foresight/2020-strategic-foresight-report_en.
[39] OECD (2019). Strategic foresight for better policies. Retrieved 24 June 2021, from https://www.oecd.org/strategic-foresight/ourwork/Strategic%20Foresight%20for%20Better%20Policies.pdf.
[40] O. Shevchenko, Z. Varnalii, G. Kharlamova, N. Kuzmynchuk, Models for assessing crisis dynamics in disparities of Ukraine's regional economy to ensure the economic security of regions, J. Int. Stud. 16 (1) (2023) 177–190, https://doi.org/10.14254/2071-8330.2023/16-1/12.
[41] I. Tiutiunyk, J. Drabek, N. Antoniuk, V. Navickas, P. Rubanov, The impact of digital transformation on macroeconomic stability: evidence from EU countries, J. Int. Stud. 14 (3) (2021) 220–234, https://doi.org/10.14254/2071-8330.2021/14-3/14.
[42] M.K. Wyrwicka, O. Erdeli, Strategic foresight as the methodology of preparing innovation activities, Market. Manag. Innov. 2 (2018) 339–350, https://doi.org/10.21272/mmi.2018.2-26.
[43] K. Cuhls, From forecasting to foresight processes – New participative foresight activ-ities in Germany, J. Forecast. 22 (2003). https://onlinelibrary.wiley.com/doi/abs/10.1002/for.848.
[44] Y. Kharazishvili, Systemic Security of Sustainable Development: Assessment Tools, Reserves and Strategic Implementation Scenarios; Monograph; Institute of Industrial Economics, National Academy of Sciences of Ukraine, Kyiv, Ukraine, 2019, p. 304. https://iie.org.ua/wp-content/uploads/2019/02/Harazishvili_monograf_2019-ost.pdf.
[45] E. Ruspini, P. Bonissone, W. Pedrycz, Handbook of Fuzzy Computation, CRC Press, 2020.
[46] J.C. Turner, Modern Applied Mathematics. Probability. Statistics. Operational Research, English Universities Press 1970, London, 1970, p. 502 (January 1, 1970).
[47] J. Van Gigch, Applied General Systems Theory, Harper & Row, London, UK, 1978.
[48] Y. Kharazishvili, O. Sukhodolia, G. Riabtsev, O. Kalinin, G. Us, Y. Lunov, Adaptive response methodology for sustainable energy systems of the national economy In the security dimension, Migr. Lett. 21 (S7) (2024) 1785–1804. Retrieved from, https://migrationletters.com/index.php/ml/article/view/9194.
[49] Y. Kharazishvili, V. Lyashenko, D. Bugayko, I. Ustinova, O. Shevchenko, O. Kalinin, Justification of the identification of threats and problematic components of sustainable regional development in the security dimension, E3S ISCMEE 2023, in: Proceedings of the Web of Conferences 408, 2023 01028, https://doi.org/10.1051/e3sconf/202340801028.
[50] C. Leondes, M. Aoki, Modern Control Systems Theory, McHraw-Hill, New York, NY, USA, 1965.
[51] G. Fuertes, M. Alfaro, M. Vargas, S. Gutierrez, R. Ternero, J. Sabattin, Conceptual framework for the strategic management: a literature review—descriptive, J. Eng. 2020 (1) (2020) 6253013.
[52] F. Gluck, S. Kaufman, A.S. Walleck, The four phases of strategic management, J. Bus. Strategy 2 (3) (1982) 9.
[53] J.D. Hunger, T.L. Wheelen, Essentials of Strategic Management, 5th ed., Prentice Hall, 2020.
[54] O. Sukhodolia, Y. Karazishvili, H. Riabtsev, Enerhetychna Bezpeka Ukrainy: Perspektyvna Model Upravlinnia Ryzykamy, NISD, Kyiv, 2023, p. 152, https://doi.org/10.53679/NISS-book.2023.01 [Energy security of Ukraine: a promising model of risk management](in Ukrainian).
[55] Y. Kharazishvili, A. Kwilinski, O. Sukhodolia, H. Dzwigol, D. Bobro, J. Kotowicz, The systemic approach for estimating and strategizing the energy security: the case of Ukraine, Energies. (Basel) 4 (2021) 1179239, https://doi.org/10.3390/en14082126.
[56] Cabinet of Ministers of Ukraine (2021). Skhvalennia Stratehii enerhetychnoi bezpeky: Rozporiadzhennia Kabinetu Ministriv Ukrainy Vid 04. 08. 2021 r. № 907-r. [Approval of the Energy Security Strategy: Order of the Cabinet of Ministers of Ukraine dated 04.08.2021 No. 907-p.] URL: https://zakon.rada.gov.ua/laws/show/907-2021-%D1%80#Text (in Ukrainian).
[57] B. Rostami-Tabar, M.M. Ali, T. Hong, R.J. Hyndman, M.D. Porter, A. Syntetos, Forecasting for social good, Int. J. Forecast. 38 (3) (2022) 1245–1257.
[58] EIS (2020). Methodology report, 20.05.2020. URL: https://ec.europa.eu/docsroom/documents/41861.
[59] Y. Kharazishvili, A. Kwilinski, Methodology for determining the limit values of national security indicators using artificial intelligence methods, Virtual Econ. 5 (4) (2022) 7–26, https://doi.org/10.34021/ve.2022.05.04(1).