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THE MIX OF RESOURCES, SECURITY AND SUSTAINABILITY OF THE ENERGY COMPLEX IN ROMANIA IN THE EUROPEAN CONTEXT

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Abstract

This article presents the results of the research on energy activities in Romania by highlighting the variants of the mix of energy resources, the mix of production alternatives, and ways of energy consumption. The uneven distribution of resource ownership in EU member states is a comparative advantage for Romania, which has significant primary energy resources. The impact of the energy crisis on the new economy is described, and the concept of transitional recession is launched, emphasising the reduction of risks associated with the lack of energy resources in Romania and the EU until 2030. Trends in the production of energy resources are highlighted. The security and environmental problems related to energy consumption under conditions of overlapping crises in the EU and Romania are associated with solutions resulting from the conceptualisation of the *adaptive energy market*. Aspects of managerial applications in the field of predictable/unpredictable events in the field of energy in Romania are reported. Therefore, the foundations are laid for a formalisation model of the security and safety conditions and the premises for the independence of Romania's energy. On this basis, the maximisation of the output of the security and safety states model is pursued and the premises for Romania's energy independence, respectively, the minimisation of environmental effects, are systematised. Based on the calculations and evaluations of three scenarios, a variant of the electricity/energy production mix results that meets the objectives pursued. In fact, a block scheme of approach is proposed, from the vision to the roadmap for the energy field in Romania, the idea of open energy autonomy being launched, considered appropriate with the ecoeconomic, productive-industrial behaviour of Romania.

Keywords: Security, mix of energy resources, adaptive energy market, open energy autonomy.

JEL classification: C67; D24; E27; L72

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Introduction

The decision-makers, the primordialist economic and strategic institutions at the global level accept the conclusion of the irreversibility of the appearance of an energy shock similar in form and content to the oil crisis of 1973. But the *conceptual silence* of the last decades of the world's economic existence with regard to energy represents an error of the strategic approach, the objective cyclicity of almost all economic phenomena and processes being ignored. The general observations show that the period of recession, of overcoming difficulties, and the potential of resilience in the field of energy are different from one country to another. In some countries there are *falls, temporary stagnation* in the functioning of economic structures; in others, the decline is recorded at time-delayed intervals, in relation to the global developments of contemporary economies; a number of states (economies) went into recession before their energy liberalisation and energy stabilisation programmes were clearly formulated. Currently, it is necessary to ensure a clear path for other types of essential technologies: green energy, decarbonisation, biotechnologies, and genetics.

The concerns of EU member states and Romania are focused on ensuring the sufficiency of operational energy resources for productive-economic processes, mainly for transport in network economies and in productive-economic processing. The reduction in consumption, associated with the optimisation of networks, represents the classic approach to solving the problem of providing energy resources. The reaction to solutions to energy crisis situations is given by the emergence of *industrial clustering*, to which are added productive economic relocations based on comparative efficiency. The traditional quantitative vision to highlight new accumulations of natural energy resources is in operational decline. The access or maintenance of access to the global energy market is the central concern of state entities for their energy security. The uneven distribution of resources in EU member states is a comparative advantage for Romania, as a possessor of significant primary energy resources. Relatedly, attention is paid to the effects on the environment (Gâf-Deac et al., 2015). It is found that in the effort to develop the updated/crisis energy strategy in Romania, the macroeconomic variables are exogenous, and the microeconomic ones are frequently endogenous. Any scenario regarding an energy strategy can be based on at least one hybrid model, with open potential, with participatory weights of different resources and capabilities. Romania can become a regional supplier of energy security, to the extent that clean energy, along with nuclear energy, offshore and onshore hydrocarbons, respectively (Iuga and Dudău, 2018), contribute to the complete quantitative assurance of primary energy resources.

The structure and approach within this article are built starting from the critical developments recorded in recent years in the global, European, and national energy system, reflected in studies and research to know the causes, effects, and identify the premises for resilient solutions. Research based on the concept of *inputs - transformations - outputs* (energy realities in Romania, the transitional recession, the appearance of disorganisation in the economic and energy structures, the manifestation of risks) ensures the combination of data and information through quantitative, qualitative, inductive, analytical, synthetic, and comparative. In this context, the delimitation of the problem is carried out (requirements for a mix of resources, security, and energy sustainability), the proposal for the conceptualisation of the adaptive energy market, of open energy autonomy is advanced, and elements of vision, scenarios for ensuring energy in Romania are presented support for appropriate decisions in the field.

The work is structured in five parts: introduction, scientific literature review, research methodology, results, and discussions, and conclusions. In the literature review section, the main concepts of energy security are described and analysed and points of view are presented regarding ways to ensure resources in the context of limiting factors at a global, geostrategic, economic, and sustainable level. The methodology section presents and argues the energy realities in Romania based on the trinomial *inputs - transformations - outputs*. The research results are presented on the basis of the requirements for a mix of resources, security, and energy sustainability. In the end, the conclusions and limits of the research regarding the proposal for the conceptualisation of the adaptive energy market, of open energy autonomy are presented, and elements of vision, scenarios for ensuring energy in Romania are presented, as support for appropriate decisions in the field. Directions for future research allow the realisation of IT applications to optimise the proposed scenarios for Romania's energy security.

1. Literature review

Knowledge in the field proves difficult as a result of developments, often without predictability, in terms of the definite existence of resources, their spread in diversified geographic, geological, geostrategic areas, variable demands and disproportionate energy consumption, different levels of infrastructural development, economic and societal challenges, environmental challenges and regional conflicts, markets facing volatile fuel prices, incompletely defined technologies (for H₂, CO₂, renewables), local energy strategies, tactics, and programmes with specific features, global strategy inconsistency, contradictory environmental developments environment, and security of supply in the medium and long term. In the 2022 country report on Romania, it is stated that the business sector, small and medium-sized enterprises in Romania are the main beneficiaries of energy, but among them there are some structural deficiencies related to the transport infrastructure, excesses of bureaucracy, often weak public administration reactive, frequently unpredictable legislative framework, insufficient application of corporate governance principles (2022 Country Report on Romania, 2022). The 5.9% growth of Romania's economy in 2021 compared to 2020 was based on energy resources (3.4% higher, of which +13.3% imports, in the situation where the national production of primary energy resources is higher by 1.9%). The import of coal increased by 16.5% and the import of natural gas reached 2,230 thousand tons of oil equivalent (toe). The energy balance was achieved in a difficult macroeconomic and microeconomic framework, with uncertainties arising from the overlap of crises (Note on the forecast of the energy balance 2022-2025). Institutional reforms require a longer time for implementation, but the pre-energy crisis visions are missing. For example, the much-accelerated commitment to decarbonisation without ensuring replacement capacities for entities using fossil fuels, the delays in the operation of offshore exploitation in the Black Sea (Delloite/Transgaz, 2018), as well as the lack of a commissioning programme of yet two electronuclear groups in Cernavodă.

The concept of energy security is defined by Cherp and Jewell (2014) from the strategic and tactical perspectives of nondependent, quasi-full provision of energy and primary energy resources. Recently, Ashraf and Bocca (2023) showed that energy security and sustainability are complementary, and in the short term the focus is on clean energy supply, delineating six areas in which to pursue the energy transition: 1) demand, 2) regulations and incentives, 3) trust and collaboration, 4) supply, 5) stability and resilience, 6) system security. The listed

alignments, also valid for the energy system in Romania, are not competing, but complementary, and the need for integrated solutions, characterised by simultaneity, is being noticed.

Some authors (Buonomano, Barone and Forzano, 2022) show that there are challenges and requirements to develop multidisciplinary approaches for the decarbonised economy, aiming at achieving a just and successful energy transition, reducing sources of conflict and inequity generated by geopolitical tensions. On this basis, long-term uncertainty is combated and the prerequisites for energy security, environmental protection, and energy accessibility are created. The progress of the energy sectors in the countries of South-East Europe, including Romania, has been marked by challenges and opportunities (Buzogany and Davidescu, 2022), aiming to achieve compliance of the countries in question with the EU energy policy (Borozan, Mateska and Krstevski, 2021). Hybrid energy system optimisation methods (Zahraee et al., 2016), electricity market pricing models considering energy system flexibility and savings introduction (Wesseh and Lin, 2022), and examining the impact of energy source variability on demand response flexibility for consumption (O'Connell et al., 2021). At the same time, Sutrisno and Alkemade (2020) research the resilience of the EU gas infrastructure from the perspective of competition, endogenous changes, and the potential of renewable energy to contribute to energy security. Regarding alternative fuels in the future European energy system, relevant conclusions were obtained by Stančin et al. (2020), and Guzović et al. (2022), which speak of recent advances in the form of methods, policies, and technologies to support the development of sustainable energy systems. In the field, the intermittent and stochastic nature of renewable energy sources is observed; intermittency has costs, causing consequences and difficulties in forecasting (Notton et al., 2018).

Sauvageot (2020) foreshadowed the EU's dilemma between interdependence and energy security in the situation where Russia is dominant in the category of hydrocarbon producers and Ukraine also plays the role of a transit country (Damian and Toma, 2022). In the context of concerns for the formalisation of energy security/security at the local, national, and regional level, topics such as the energy transition as a response to the energy challenges of the post-pandemic reality (Gribkova and Milshina, 2022), the sociotechnical vision regarding security in the energy transition toward sustainability (Kivimaa et al., 2022; Davidescu, 2018), the economic performance and sustainability of the companies engaged in the production and distribution of electricity in Romania (Grosu et al., 2022), the restructuring of coal mining in Romania between the climate crisis and the energy transition (Tomescu et al., 2022), or the performing systems for increasing energy efficiency (Diaconu et al., 2019). In a global scientific plan, some *integrated assessment models* (MEI) are formalised that show the interactions between the economy, energy, agriculture with the field of climate, the environment. Clark et al. (2014) point out that the models in question are simplified, stylised numerical approaches to represent highly complex physical and social systems. With their help, scenarios are generated, possible medium- and long-term trends for gas emissions, and climate change hypotheses. In the general European energy framework, a paradigm shift is being witnessed *from dependence to diversity* (Chalvatzis and Ioannidis, 2017). For example, the dependency metric for the primary energy fuel mix of EU member states, using proxy indicators for diversity and concentration (Shannon Wiener and Herfindahl-Hirschman indices), shows that the diversity of energy supply in the EU has improved from 1990 to 2017 with 14.2% (SWI) and 22.6% (HHI). In this framework, the interrelationships between dependence and diversity express the increasing role of renewable sources in the field.

The specialised literature shows that the input-output model is dominant in energy analysis problems, even multifactorial (Guevara and Domingos, 2017). This is the approach assumed in the present work, which brings new, extended contributions to expressions of interest for the vision and concept articulated between resources, security and energy sustainability in Romania. An important approach in the literature, representing support and complementarity for the present paper, refers to the physical supply of energy resources for an adequate mix aiming at a multiregional insurance framework. The Multi-Regional Physical Supply Use Table (MR-PSUT) for multiple variables improves the accuracy and reliability of energy analysis (Aramendia et al., 2022) and is suitable for such an approach. The authors point out that the tables and matrices in question overcome some limitations of input-output analysis that describe the chain of conversion/use of resources and energy only in energy terms. The Physical Supply Use Table framework is extended to a mathematical structure with symmetry, to which is added a matrix of resource extraction (upstream of the energy conversion chain), respectively, downstream energy use by final demand sectors, which allows and inverse input-output calculations. Energy analysis is an outstanding tool for researching current challenges in energy: demand, consumption. The analysis has an informative role, it can show the role of some factors in the energy-GDP relationship, it helps to establish the options for reducing consumption, to plan the transition towards renewable sources, and it signals situations regarding the depletion of nonrenewable natural resources. The type of Energy Input Output (EIO) analysis proposed by Aramendia et al. (2022) distinguish between 1) the traditional Energy Extended Input Output (EEIO) approach, where energy footprints are calculated by premultiplying the total demand matrix with a direct energy intensity vector, 2) the hybrid EIO analysis, which describes the flows of energy in physical units and the rest of the economy in monetary terms, and 3) purely physical EIO analysis. In this context, the authors propose a *unified energy analysis framework* based on physical supply utilisation tables (PSUT). Such tables/matrices are used to develop Physical Input Output Tables (PIOTs) using *Make and Use* approaches. From these PIOTs, further physical EIO analyses are performed. As such, the multifactorial energy input-output model could be developed by coupling such PIOTs with monetary input-output tables (MIOTs). Therefore, the diversity of new methods and tools available for energy analysis is recognised, which is also of interest in the present work, useful in estimating the effects of changes in the final demand.

In modern economic analyses, the idea appears that the changes in the energy production and supply system with liberalised prices, in other words, the transition to *market energy*, produce conventional conjunctural disorganisation in economic structures. The transition was defined by the World Bank (Gelb, 1996) as the movement of economic structures *from plan to market*. Blanchard and Kremer (1996) showed that the more precise arguments for the conceptualisation of the transition refer to the transition of economic structures *from the plan and planning institutions to the market and market institutions*. Maintenance of parts of existing energy production and supply networks explains the gradual transition. To the transition, the concrete, direct participation of the state with subsidies and compensations to companies and individual consumers, is added, to counteract disorganisation and shocks. The forecast structure until 2030 for the production of energy from fuels shows that the natural limitation of the energy resources of the EU is recognised, respectively, the uncertainty of developments in the field of domestic hydrocarbon production (Bohringer and Loschel, 2006). For example, to maintain the current level of nuclear energy production capacity in the EU (15%-16% of EU energy production in 2030 and 2050, stable generation capacity, at

the level of at least 100 GW), investments of approximately 450 billion euros would be necessary, otherwise 90% of the existing reactors would be closed (Stančin et al., 2020; Simson, 2022). Renewable energy resources (wind, photovoltaic, hydro, biomass) are abundant, but play a smaller role in the European production and consumption structure. The process of separating the trends between the increasing meaning of the economy of a country (or, in general, the global plan) and the decreasing one of the environmental impacts is illustrated by *increasing the productivity of the natural resource*. At a regional and European level, between 2000 and 2020, resource productivity expressed in euros increased on average by 2.2% per year.

The geological-geographic endowment with deposits of energy substances expresses the fact that each EU Member State, including Romania, has a specific energy mix. The level of possession of primary energy resources indicates the self-sufficiency of national energy. A common European energy policy is being processed for updating, as the EU Council has signalled since 2008, within the framework of the Common Foreign and Security Policy (CFSP), that up to 75% of oil and gas will have to be imported by 2030. Mitigation of the possible *energy shock* in economic structures and individual consumers in Romania and the EU is now (2022/2023) carried out through compensations, subsidies, attempts to re-centralise the energy market (*restriction of liberalisation*), or the reintroduction of the regulated market. These measures in the critical field of energy have no strategic potential, but only conjunctural valences, dependent on geostrategic developments. At the same time, other conjuncture decisions are added to these measures, such as: 1) temporary reduction of the intensity of decarbonisation activities, 2) increasing concern for new renewable energy capacities, 3) obtaining energy from waste, 4) eco-saving energy, etc. The observed paradigm is the following: the energy crisis causes less energy to be consumed in Romania and the energy consumed is bought at higher prices.

2. Research methodology

The main purpose of the analysis in this paper is to establish recommendations regarding energy activities in Romania by highlighting the variants of the mix of energy resources, alternatives composed of production and methods of energy consumption on the way to energy security and sustainability. Equally, the purpose of the research consists in deepening and developing knowledge for scenarios, variants, security solutions, and sustainability of the provision of energy resources at the national and European level. The main objective of the research is to argue the study methodology by formalising the model that allows variations of the commandable values (outputs) included in the energy strategy for Romania for the period 2023-2030 and, on this basis, to obtain foundations, prioritisation, and practical decisions to combat or to improve energy crisis situations.

The energy crisis found in the aggregate of overlapping crises for the period 2018-2023 led to the delimitation of the research objective in this paper. For the mix of resources, energy security, and sustainability, recourse was made to clarifying the terms of operation, adopting the input-output technique, collecting and systematising data and information of influence/exception in the field of energy on a national and European level, outlining the research rationale. The requirement to solve certain problems to achieve the objective of providing an adaptive energy market concept is a support for research purposes. A contribution of the research aims to understand the phenomenon of crisis and the lack of

energy solutions, with the possibility of adapting and developing the entry-exit technique to formalise a tactic put in the service of the energy strategy in Romania. In a first stage, the formal organisation of the data was resorted to, and then the order of successive operations included the primary analysis of the information (correlations, reports), in a correlated, logical, algorithmic manner. In the present case, it began from *a state of fact* (the energy crisis). During the investigation, problems and dysfunctions were detected, and on this basis a model was developed to formalise the security, safety conditions and the premises of Romania's energy independence through the operation of an adaptive energy market.

In the research we used a *formalised model*, which we elaborated, outlined, constituted, and built, a support tool on which to slide values of the logical chain *input-processing/transformation-output* with possible feedbacks (inverse, reactive, correction loops) if the controllable values (programmed, required, imposed, planned, etc.) are not targeted/achieved. To formalise the model, the following phases were completed: 1) the inventory of the elements generating critical situations, 2) the parameterisation and mathematical symbolisation of these elements, 3) the realisation of associations, reports and correlations, determinations between parameters, 4) (written) *formalisation* of the system of equations, and 5) the graphic presentation of these relationships. As such, the stages completed in the presented research are the collection and classification of data, placing the data in block schemes, and the symbolic mathematical formalisation of the model that allows variations of the input parameters.

3. Results and discussion

3.1. The conceptualisation of the *adaptive energy market*

In this research, we launch the concept of *adaptive energy market*, which determines the manifestation of innovative managerial skills within companies, respectively, the possible introduction of new management methods and techniques related to the New Economy resilient to the energy crisis. In this context, it would be possible for modern management to register convergence and analogous manifestation, similar to Darwinian analytical formulas (Gâf-Deac, 2010), as the applicability of organisational and leadership methods and techniques hyperadapted to crises, in general, expands, and the energy crisis in particular, through their universalisation. Thus, a destructuring of current management methods and techniques can be recorded, in the sense of mitigating the limits, frontiers, methodological boundaries of action of managers in situations of energy insecurity. They become freer in terms of procedure, avoiding the adoption of preconceived management methods and techniques which, traditionally, respectively, conventionally, are accepted in the managerial science of the ordinary, current economy. Inefficient energy markets are considered the result of inefficient management behaviour. Latent, *small*, and *excessive* risks in the energy field, which is in crisis, can be found both in front of the consumer and the management, respectively, in the markets where the energy competition takes place. In an adaptive energy market, managers operationalise their organisational and leadership intentions, so they aim to achieve conventionally expected results. In another subvariant, the competitors obtain results that confirm the *unpredictability of energy events*, and, thus, they act in the operational field marked by the *hard statistics* of the closure in *definite unpredictability* of some events that cannot affect their organisation and management (Figure no. 1), in conditions of energy crisis.

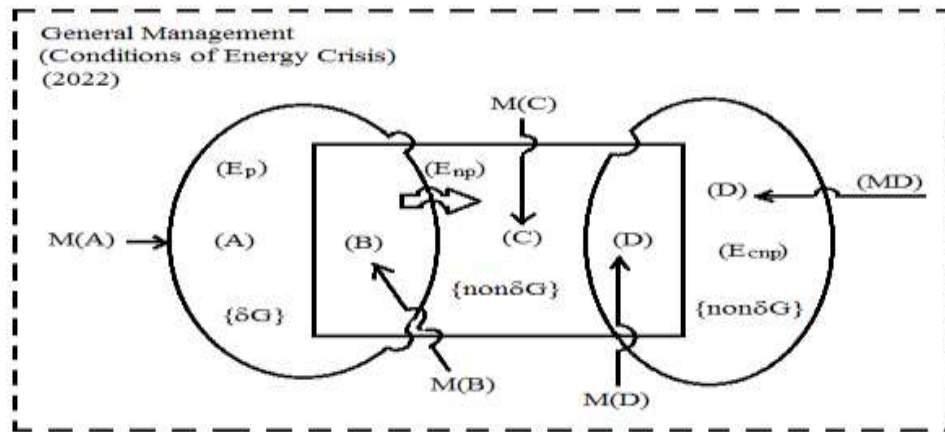


Figure no. 1. Managerial applications in the field of predictable/unpredictable events in the field of energy in Romania

Source: Authors

in which:

(A) = field of predictable energy events; (B) = field of predictable energy events, deduced from unpredictable energy events; (C) = field of unpredictable energy events; (D) the field of definitely unpredictable energy events; (E_p); (E_{np}); (E_{cnp}) = energy management formulas; (E_{np}) = unpredictable energy events; (E_p) = predictable energy events; (E_{cnp}) = certainly unpredictable energy events; {δG} = Gaussian distribution; {nonδG} = Gaussian non-distribution; {δnonG} = non-Gaussian distribution.

Thus, in the management of the future of energy, respectively, in the New Economy, the most important action will be the exploration and exploitation of the qualitative informational field and, by extension, in the second plan, only articulated of the quantitative one. In a practical context, qualitative management methods in the field of energy can be accompanied by quantitative techniques of organisation and management. Therefore, management methods and techniques will not only be built to overcome or counteract the energy crisis in the New Economy, but also to balance its *weight*, thus showing the action compatibility for exploring and exploiting opportunities, in order to obtain, through resilience, conventionally accepted, respectively, imposed results.

3.2. Vision, models and scenarios for energy in Romania

Starting from our own resources and capacities to which import resources are added, taking into account consumption requirements, we advance a model of ensuring Romania's energy security and independence from production, transport-supply to energy consumption, minimising on this algorithmic route the anthropogenic, specific, environmental impacts (Figure no. 2).

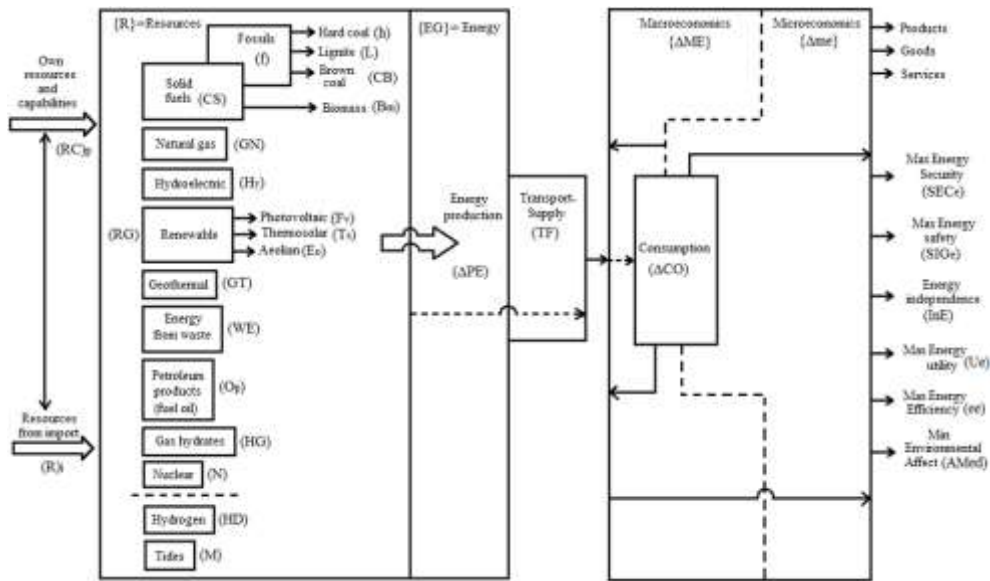


Figure no. 2. Model for the formalisation of the security, safety and prerequisites for Romania's energy independence

Source: Authors

Researching the assumptions of functional resilience of scenarios of primary energy resources and energy production capacities in the SNE in the medium and long term can be done by modelling, mainly starting from a binary (yes/no) feasibility signalling model variations in the overall structure of energy demand/consumption in the Romanian economy (Van Beeck, 1999; Wei et al., 1999; Lanza and Bosello, 2004). Appreciation variables are considered for each eligible scenario: $m_{a,b}$ (with value zero before the start of the scenario and value 1 when the start/start is given for acceptance/application of the scenario in question). Thus, we are dealing with a time series of the form *Before (year) - Present (p) - Future starting today (v)*. Within each scenario (S1, S2, S3), a prediction is identified, similar to the probability or certainty of introducing different amounts of primary energy resources that Romania naturally has on its territory and in its subsoil. A low-pass filter allows fluctuations to be ignored when building the long-term vision ($T_{i,j}$). In fact, the aim is to develop a statistical model with the potential to estimate scenarios S1, S2, and S3. This conception is support for a Generalised Additive Model (GAM), which, according to Gareth et al. (2021), means form of *supervised learning*. The Generalised Additive Model developed for the first time in this work has the following form:

$$\begin{cases} [(CS)(f)+(Hy)+(RG)+(N)]+[(GT)+(WE)+(Op)] \xrightarrow{(\Delta PE)} \{EG\} \\ [(HG)+(HD)+(M)]=0 \\ \{EG\} \rightarrow (TF) \xrightarrow{\frac{[\Delta ME]}{[\Delta me]}} (\Delta Co) = \max \{ (SECE) \cdot (SIGe) \cdot (UE) \cdot (ec) \} \\ f(\{EG\}) \rightarrow (AMed) \end{cases} \quad (1)$$

The meanings of the variables in equation no. 1 are explained in figure no. 2, which represents the formalisation model of security, safety and premises for Romania's energy independence.

It is the basis for the emergence and development of a scalable decision tree boosting system (XGBoost) (Chen and Guestrin, 2016). Following this type of approach, the variants of scenarios with data from the official statistics are systematised (Table no. 1).

Table no. 1. Maximisation of outputs from the model of security, safety states and premises for Romania’s energy independence (minimisation of environmental effects)/MWh

| Symbol | Installed power | Scenario 1 (S1) | Scenario 2 (S2) | Scenario 3 (S3) | {EG}/ΔPE | (ΔCO)/{ΔME} | (ΔCO)/{Δme} | |
|--------------|-----------------|-----------------|-----------------|-----------------|------------------|---------------|---------------|--|
| (CS) | (h) | 44 | 52 | 52 | S ₁ = | [0.444/0.448] | [1.202/1.193] | [1.090/1.082] |
| | (L) | 995 | 987 | 987 | | | | |
| | CB | - | - | - | | | | Max (SEC _e) |
| | (Bm) | 107 | 64 | 80 | | | | (±) (±) (±) |
| (GN) | 2617 | 1010 | 1200 | 1950 | | | | Max (Siege) |
| (Hy) | 6642 | 1836 | 2100 | 2100 | | | | (±) (±) (+) |
| (RG) | (Fv) | 1392 | 364 | 460 | S ₂ = | [0.517-0.521] | [1.033/1.024] | [0.940-0.929] |
| | (Ts) | 40 | 20 | 40 | | | | |
| | (Eo) | 3015 | 2599 | 2610 | | | | |
| (GT) | (min) | 50 | 50 | 60 | | | | Max (U _e) |
| (WE) | 6 | - | - | 10 | S ₃ = | [0.476/0.479] | [1.122/1.115] | [1.018/1.011] |
| (Op) | (min) | 10 | 10 | 10 | | | | |
| (HG) | - | - | - | - | | | | |
| (N) | 1413 | 1366 | 1366 | 1366 | | | | Max (ee) |
| (HD) | - | - | - | - | | | | (±) (±) (±) |
| (M) | - | - | - | - | | | | min (AMed) |
| Total | 18653 | 8298/8358 | 8886/8946 | 9655/9735 | | | | (±) ₁ (±) ₂ (+) ₃ |
| | | | | | | | X | |

Source: Calculations based on INS Bucharest statistical data, 2018-2020

The interpretation of the calculations and the results are presented next.

- The multitude of primary energy resources (List by type) represent the realities of geological deposits explored in detail, homologated quantitatively and qualitatively (contents of useful substances) characterised as being exploitable with current mining technologies, proven of economic interest, according to the National Agency of Mineral Resources (ANRM).

- The resources of hydrogen, methane hydrates, and tidal energy do not participate, at this stage, in the energy mix; however, since their existence is being confirmed, technological research is being carried out for homologation and validation of their introduction in the near future into the economic/energy circuit.

- The installed current power (18,653 MWh) in Romania is shown to be sufficient in the National Energy System (SEN).

- In the S1 scenario, the use of installed power by types of primary energy resources refers to the current (2022) operating structure (maintenance operations are estimated for nuclear energy, with relatively reduced adjustment of the operating capacity for procedural technological reasons).

- In the S2 scenario, the use of installed power by types of primary energy resources refers to the operating structure moderately adjusted (transitory) compared to the values in S1 by increasing the supply of coal, lignite, biomass, natural gas, hydroelectric, photovoltaic, thermosolar and wind.

- In the S3 scenario, the use of installed power based on types of primary energy resources refers to the operating structure significantly adjusted compared to the values in S2 by attracting some energetic substances (energy from waste) and increasing the supply of biomass, natural gas, geothermal.

Relative to real/requested consumption and insurers (9,000 - 9,048 MWh), the functional influence values on energy production, in macro and microeconomics, are calculated; for energy production, the favourable influence is found in S2, and for the macro and microeconomy, the S3 scenario is fully conclusive. Typically, energy production turns out to be more decision- and investment-intensive (as an effort) than the other scenarios. Outputs/results show maximisation of model controllable values and minimisation of environmental effects from an operational perspective of the energy domain.

Based on the calculations and assessments/evaluations in scenario 3, an electricity/energy production mix of 9,735 MWh results: hydro = 2,100 MWh (21.57%); nuclear = 1,366 MWh (14.03%); coal = 1,039 MWh (10.67%); renewables (photovoltaic, thermo-solar) = 860 MWh (0.88%)/ wind = 2,610 MWh (22.18%); biomass = 90 MWh (0.09%), natural gas 1,950 MWh (20.03%), geothermal 60 MWh (0.06%), petroleum products (fuel) 10 MWh (0.01%), energy from waste 10 MWh (0.01%), evaluated as feasible, moderate in terms of sufficiency, insurance for the energy needs in the Romanian economy in the period 2023-2030. The S3 variant is proposed to be taken up and, in this way, decision makers in the economy, government and politics, finance and investors, developers of tactics and plans of measures and actions to overcome the current energy crisis can demonstrate commitment on a common front of resilience and consolidation of the national energy system. The observation with a relevant degree of significance refers to the fact that in all 3 scenarios for possible security, safety, and energy independence formulas of Romania, the participation of its own energy resources has the highest weight (on average 95-98%) in the formation of a mix adequate energy, the participation differences representing the conjuncture imports of some primary energy resources or electricity from the interconnected/inter-operationalised European Energy System. Thus, Romania can become a supplier of energy security for the EU. As such, the following are required: a) vision, b) strategy/programmes, and c) actions/implementation to attract each type of primary indigenous energy resource to the national energy complex. In fact, the proposal of a block scheme to structure a road map for Romania's energy sector proves to be useful/opportune (Figure no. 3).

Next, the symbolic mathematical model with the relationships, generated meanings, and parameters characterising the composition of primary energy resources, production, transport, and energy consumption in Romania is intended for processing for informational programming. The obtained software can act as a tool for value multiplication of input parameters, transformations, and obtaining controllable values (outputs) for the scenarios developed in the field. On this basis, we arrive at the substantiation of the decision to choose/assume a feasible scenario of security, safety, independence, and sustainability in Romania's energy complex.

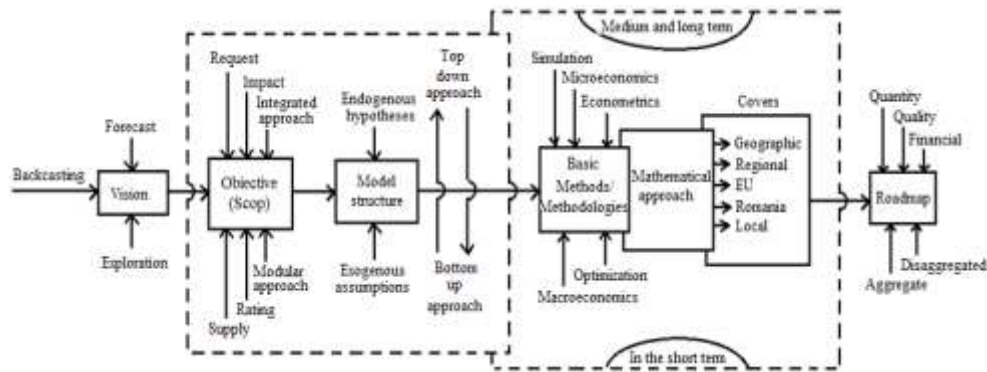


Figure no. 3. Proposal for a block diagram approach from vision to road map for the energy field in Romania

Source: Authors

Conclusions

In the context of the study, Romania is required to diversify its energy mix, increase its national interconnection capacity (currently, the interconnection capacity of electrical networks is less than 10%) and modernise its energy transmission networks. Romania's dependence on natural gas from the Russian Federation can be eliminated by accelerating the operation of offshore deposits in the Black Sea, onshore deposits on the national territory, the exploitation of methane gas hydrates from the bottom of the Black Sea, as well as the exploitation of hydrogen sulphide to separate hydrogen as the fuel of the future.

In fact, we are launching the concept of open energy autonomy, which we believe fits the eco-economic, productive-industrial behaviour of Romania. The design of the energy mix should be supported by mathematical models, software programmes (simulation-modelling), in which the constraints (incentives) and the objective function depict the system stability and operating performance (investment, maintenance and operation). One can adopt the device-level control strategy, aggregated with the system-level control strategy, with the result reflected in a standard normal distribution. The need for clearer, deeper knowledge of what is happening with energy at present emphasises the need to complete the economic theory of the general transition, within which the notion of a possible *transitional recession* can be found with relevance. This is just one characteristic, part of the total, overall experience, regarding the postcentralised evolution towards even greater decentralisation of economies already dominated by computerised, digitised super-hyper-technologies.

The results of the research in the present work can be found synthetically, in a coherent and correlated formula, in recommendations to identify decisions in the face of risks associated with the lack of insurance with energy resources, which explains the gradualism of the transition in the field of energy in Romania. The launch of the concept of an adaptive energy market, the increase in resource productivity, the separation between the increasing meaning of the economy and the decreasing meaning of the impact on the environment, the introduction of management methods and techniques related to the New Economy resilient to the energy crisis, a new decision-making behaviour in situations of energy insecurity, all of these are

associated with the three scenarios to maximise the results of the security, safety, and premises model for Romania's energy independence. At the same time, through the expansion of some studies and research in the field, the concept of open energy autonomy, of ecoeconomic, productive-industrial behaviour of Romania is launched with a roadmap-type block scheme, supported by a Generalised Additive Model elaborated in the present work.

The formalised model thus becomes a support tool that allows sliding the values of the input-processing / transformation-output logic chain with possible feedbacks (inverse, reactive, correction loops) if the commandable values (programmed, required, imposed, planned, etc.) are not reached. The transition from the formal model to the application model is achieved by: knowing the reality on the ground (from the field of energy); the identification of relationships, ratios, determinations, conditions, restrictions, interrelationships, etc., between the variables that characterise reality; mathematical symbolisation of variables; symbolic mathematical equation setting of variables; outlining the formal mathematical symbolic (equational) model. As an extension of our research, computer scientists could integrate the formal model into a computer application. The application will provide strategic decision makers with programmes for *input-output* variations and obtaining commandable values through the objective function. At the same time, the main limits of the present research refer to the fact that the approach is at the synthetic level of the *national plan in a European context*.

In this paper, we have introduced a framework that allows analysts and decision-makers to track energy flows at the national level, in a European context, overcoming the limitations of the fragmented approaches (concepts and actions) currently practised in the field. The synthetic, detail-limited description of energy flows is overcome by the conclusive and up-to-date vision presented in the paper for energy resources, security, and sustainability. The proposals and recommendations are flexible, in association, and/or complementary with results and trends derived from the specialised literature.

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