STRUCTURE AND ANALYSIS OF THE URANIUM MINING SUBSECTOR IN THE CONTEXT OF ENSURING OF ROMANIAN ENERGY SECURITY

Fîță Nicolae Daniel[1], Stănilă Daniela Sorina[2], Păsculescu Dragoș[3], Lazăr Teodora[4], Popescu Florin Gabriel[5], Mureșan-Grecu Florin[6]

[1]University of Petroșani, 332006 Petroșani; E-mail: daniel.fita@yahoo.com
[2]University of Petroșani, 332006 Petroșani; E-mail: sorina_stanila@yahoo.com
[3]University of Petroșani, 332006 Petroșani; E-mail: pdragos_74@yahoo.com
[4]University of Petroșani, 332006 Petroșani; E-mail: teomititica@yahoo.com
[5]University of Petroșani, 332006 Petroșani; E-mail: floringabriel82@yahoo.com
[6]University of Petroșani, 332006 Petroșani; E-mail: flomavon2002@yahoo.com
Corresponding author: daniel.fita@yahoo.com

ABSTRACT. The need for analysis of the nuclear subsector, which generates critical nuclear infrastructure, comes in the context in which the possible occurrence of non-supply cases with uranium raw materials, nuclear fuels and nuclear electricity, could generate major issues of national interest, with European and NATO implications. The authors consider that addressing the uranium mining subsector is a strict national security issue because the lack of nuclear raw materials, their prefabricated materials or nuclear electricity can cause enormous damage to domestic consumers, industry and the national economy, which are dependent on electricity.

Key words: uranium mining subsector, ensuring energy security

Energy security concept

The energy security of a state represents: (Bahnareanu, 2008).

- *existence, accessibility and supply of finite resources of raw materials (oil, natural gas, coal, hydrocarbons, uranium, etc.) and renewables, sufficient and available;*
- *clear and stable international/European trade agreements on access to these finite (re)sources of imported raw materials;*
- *price stability of these finite raw material (re)sources;*
- *control of transmission and distribution routes and alternatives to finite (re)sources of raw materials;*
- *the safety and security of the transformation of these finite (re) sources of raw materials into electricity;*
- *clear and stable trade agreements on trade in electricity with neighbouring countries or those of the European Union;*
- *electricity price stability;*
- *control of electricity transmission and distribution routes;*
- *accessibility of each consumer (domestic/industrial) to electricity.*

The level of security of a state is defined by the ability of that state to aggregate resources internally, to gain and maintain access to external economic resources, and any longer interruption of energy supply has a negative effect on economic growth, political stability and welfare of the citizens of a state (Baumann, 2008).

Energy security plays a very important role in the economic security of a state, for this reason it must be taken in the most serious way, and the failure to attach importance to energy security can cause catastrophic damage with insecurity and instability, endangering the welfare of the people.

Energy security is perceived as an umbrella covering energy concerns with regard to:

- *economic growth;*
- *political power.*

As distinct and overlapping dimensions of energy security, experts from the "German Centre for Applied Political Research" identify:

- *the dimension of domestic policy (state of political stability);*
- *economic dimension (energy resources and markets);*
- *the geopolitical dimension (international energy trade);*
- *the size of the security policy (securing energy infrastructure);*
- *the military dimension (national security and safety).*

The particularities of the dimensions of energy security are explained in Table 1.

Structure of the National Energy Sector

The National Energy Sector is composed of the following subsectors: - Figure 1 (Fîță et al., 2021):

- Oil Subsector:
  - *Oil Branch;*
  - *Natural Gas Branch.*
- Nuclear Subsector – Uranium;
- Mining Subsector – Coal;
- Power Subsector – Electricity.

Primary energy sources

The development of a strong energy industry of a state is conditioned by the existence of primary energy sources that are characterised by: (BP Statistical Review of World Energy, 2018):

- *diversity;*
- *accessibility;*

Table 1. *Particularities of the dimensions of energy security*

Dimensions	Particularities
Domestic policies	- investments in the maintenance and development of energy infrastructure (new construction of energy objectives or refurbishment of existing ones; - intervention in case of energy emergency (breakdowns, incidents and/or accidents); - increasing energy efficiency; - orientation of the energy mix towards alternative energies; - securing jobs and workers.
Economic	- clear rules for the functioning of the oil, gas and electricity markets; - plans for the development of energy transmission networks; - long-term contracts; - diversification of energy sources and highways; - technological innovation in the energy field; - increasing the reliability of the national energy and power system.
Geopolitics	- concerted action to secure international trade in oil, gas and electricity; - adopting a comprehensive legal framework in the field of transnational energy services; - the trend of renationalisation of infrastructure and energy companies; - the need for strategic concepts and holistic approaches, especially in relation to fragile states.
Security policies	- close cooperation with states vulnerable to terrorist attacks on energy infrastructure or piracy, including through the exchange of information, training and good practice debates; - industrialised states that consume large amounts of oil, gas and electricity, directly or through the EU or NATO, should also extend their commitment to risk management capabilities, crisis response and military and police training.
Military	- it manifests itself internally in the defence policies of the most important players in the energy market, which ultimately seek the use of military means to maintain advantageous positions.

- *safety;*
- *stable prices;*
- *ensuring the desired quantities for as long as possible.*

In relation to these conditions, the attention of the energy industry is directed towards an increasingly diverse range of primary energy sources, with increasingly different particularities.

Through the conversion made into specialised installations, these sources cover the demand for electricity and heat of the company.

Conventionally, primary energy sources are divided into two broad categories:

a) Finite sources (oil, natural gas, coal, hydrocarbons, uranium, etc.) **-** finite sources of primary energy are considered to be limited in both time and space. They are able to cover the needs of human society only for a limited period of time. The size of this time period depends on the volume of primary energy reserves to which human society has access;

b) Renewable sources - renewable sources are not limited in time, but they are not able to meet the growing needs of human society.

Uranium

Uranium is one of the primary sources of high energy concentration.

Due to its high chemical reactivity, uranium is not found in nature in the metallic state, but in the form of oxides (UO_2, U_3O_8), phosphates, silicates, etc.

The use of uranium in civilian applications is closely linked to the development of nuclear power plants (NPP).

Given the existing uranium reserves, the NPP will be able to play an important role in meeting the demand for electricity. To do this, it is necessary to solve problems such as (World Nuclear Association, 2018; 2020; 2021):

- increasing operational safety;

- lowering capital costs to levels comparable to those of fossil fuel power plants;

- safe storage of nuclear waste (including spent fuel).

The main disadvantage is the risk of nuclear accidents (Wu et al., 2019; Bian et al., 2021).

Electricity

The production of electricity is the process of transforming various forms of primary energy into electricity, in specialised installations of high complexity, called *power plants*.

The evolution of electricity consumption has made the power plants bigger and bigger; their installed powers being limited by technological, economic, environmental or security restrictions.

The power plant is a set of complex installations, which ensure the conditions for the conversion of primary energy into electricity.

Two opposing concepts of energy production can be highlighted:

a) centralised design, based on high power plants, which use primary sources with high energy concentration *(fossil or nuclear fuels)*. The power of these plants is usually higher than local consumption, implying the existence of a system of transmission and distribution of electricity. The set of power plants and transmission networks, operated in a unitary design is an *electric power system*;

b) distributed design, with small sources, located next to consumers. It is generally based on the use of light, low-energy primary sources (solar, wind, etc.). The plant is designed strictly to cover local consumption, eliminating the need to transport electricity remotely.

Uranium mining subsector

Generalities regarding the Romanian nuclear industry

Romania has over 65 years of experience in the nuclear industry, and the main national actors from the exploitation, preparation and refining of uranium ore, to the manufacture of

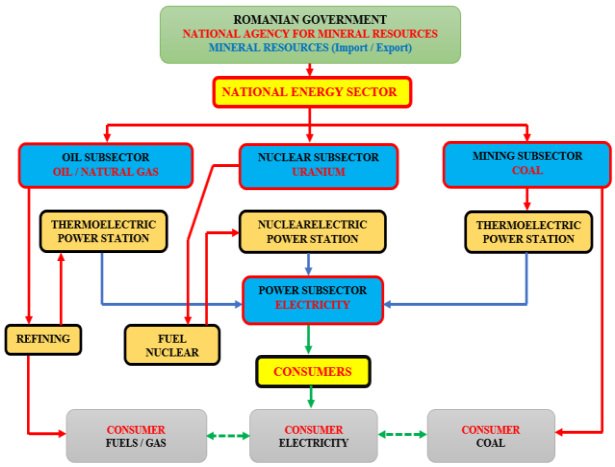

Fig. 1. Principle of operation and components of the national energy sector

nuclear fuel, the exploitation of nuclear reactors and implicitly the production of nuclear electricity are the following (Fîță et al., 2021):

- *National Uranium Company;*
- *Nuclearelectrica;*
- *Autonomous Administration for Nuclear Activities;*
- *National Centre for Heavy Water Management;*
- *Heavy Water Plant ROMAG PROD Drobeta Turnu Severin.*

The operating principle of the nuclear subsector is shown in Figure 2.

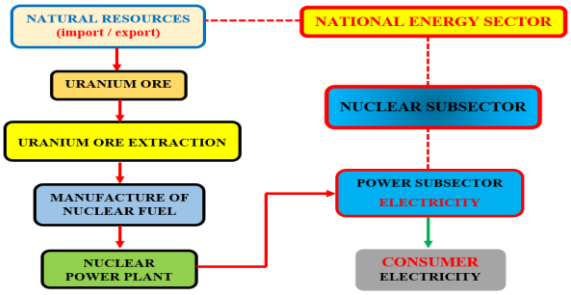

Fig. 2. The operating principle of the nuclear subsector

The National Uranium Mining System – nuclear operations

The following nuclear operations shall be carried out within the nuclear subsector:

- *management of uranium mineral resources;*
- *uranium ore extraction;*
- *preparation and processing of uranium ore;*
- *manufacture of nuclear fuel;*
- *production of nuclear electricity.*

In Romania, several state or private companies operate in all nuclear operating segments, where the main companies are:

- *National Uranium Company (www.cnu.ro) – uranium mineral resources management, uranium mining and preparation of raw materials for the manufacture of nuclear fuel;*
- *Nuclearelectrica (www.nuclearelectrica.ro) – electricity generation, thermal energy production and nuclear fuel production;*
- *Autonomous Administration for Nuclear Activities (http://www.cncan.ro/) heavy water storage.*

The Cernavoda Nuclear Power Plant has nuclear reactors designed in Canada, CANDU (CANada Deuterium Uranium), a name that summarises three of the reactor's main characteristics

- *the project is Canadian;*
- *uses heavy water as a moderator and coolant;*
- *the fuel used is natural uranium.*

Activities for Nuclearelectrica:

- *production of electricity – Cernavodă Nuclear Power Plant;*
- *production of nuclear fuel – Pitesti Nuclear Fuel Factory.*

The National Uranium Company is a state-owned company within the Ministry of Energy, established in 1997 and manages the existing uranium mineral resources in Romania.

The National Uranium Company is part of the nuclear fuel cycle in Romania, by exploiting uranium and preparing raw materials for the manufacture of nuclear fuel and contributes to increasing the share of uranium as a primary source in the energy balance of our country.

The National Uranium Company is the only producer and supplier of UO_2 (uranium dioxide) in Romania, intended for the manufacture of nuclear fuel for CANDU type reactors at the Cernavoda Nuclear Power Plant.

Currently, Romania imports uranium from other countries, because uranium mines are unproductive.

Structure :

1. Suceava Branch (production of uranium ore):
   a. *Crucea Mine – closed;*
   b. *Butusana Mine – closed.*
2. Feldioara Branch (processing and refining):
   a. *Processing Factory (sodium diuranate $Na_2U_2O_7$)*
   b. *Refining Factory (UO_2)*
3. Oravita Branch (conservation, closure, greening);
4. Stei Branch (conservation, closure, greening).

Radioactive waste is the result of daily maintenance, repair, scheduled or unscheduled plant stops and is managed completely separately from conventional waste.

The radioactive waste generated from these activities are:

- *solids (plastic, cellulose, glass, wood, purification filters, filters from ventilation systems, etc.);*
- *organic liquids (oil, solvent, scintillator liquid);*
- *flammable solid-liquid mixtures.*

For each type of radioactive waste (solids, organic liquids and flammable solid-liquid mixtures, different criteria shall be followed:

- *source of origin (building of services, building of the reactor);*
- *type of material (plastic, cellulose, metal, wood, oil, solvents, etc.);*
- *content of radionuclides (short, medium or long life);*
- *contact dose rate (low active, medium active).*

After sorting, radioactive waste is stored in special stainless-steel containers. Organic liquid radioactive waste is kept in the service building and will be solidified to eliminate potential flammability hazards. Some solid waste is compacted with a hydraulic press to reduce volume. The storage of solid or solidified radioactive waste is ensured for the entire period of operation of the plant in optimal safe and storage conditions. The final disposal of these wastes will be carried out only after conditioning in solid, safe matrices, ensuring that it will not

have a negative impact on the environment for at least 300 years.

Romania does not import nuclear fuel and heavy water because it is made domestically, and in this context, we are energetically independent from a nuclear point of view.

The complete nuclear mining cycle in Romania

Romania being a country with multiple and rich mineral resources, including uranium, has at this moment a unique competitive advantage in Europe, by the fact that on the territory of the country there is a complete nuclear cycle - Table 2 and Figure 3 - (Fîță et al., 2021):

Table 2. *Complete nuclear mining cycle in Romania*

Crt. no.	Stages	Resource type	Operator	Suboperator
1	Resource Management	uranium ore	National Agency for Mineral Resources	National Agency for Mineral Resources
2	Exploitation	uranium ore	National Uranium Company	import
				import
3	Processing and refining	uranium ore	National Uranium Company	Feldioara Factory
4	Manufacture of nuclear fuel	nuclear fuel beams	Nuclearelectrica	Pitești Nuclear Fuel Factory
5	Production of nuclear electricity	improved uranium and heavy water	Nuclearelectrica	Nuclear Power Plant Cernavodă
6	Storage	radioactive waste	Nuclearelectrica	Nuclear Power Plant Cernavodă

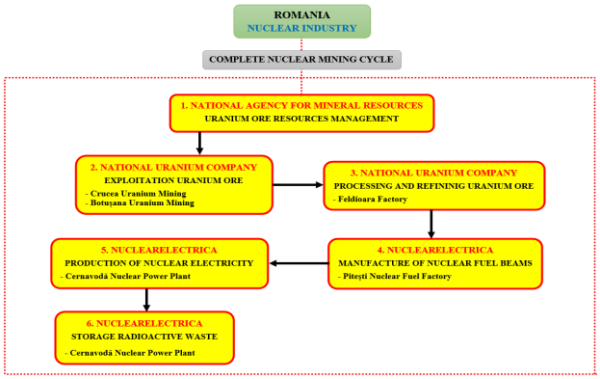

Fig. 3. Scheme of the complete nuclear mining cycle in Romania

In order for the nuclear mining cycle to be complete through the 6 stages, it is mandatory that all the 3 actors involved are present, namely (Figure 3) (Energy Minister, 2016):

- *National Agency for Mineral Resources:*
  - *uranium resources management.*
- *National Uranium Company:*
  - *import uranium ore;*
  - *processing and refining uranium ore.*
- *Nuclearelectrica:*
  - *manufacture of nuclear fuel beams;*
  - *production of nuclear electricity;*
  - *storage of radioactive waste.*

The nuclear mining pressure tool

In the context of increasing competition for power and influence globally, the EU or NATO, *nuclear energy resources* and *electricity*, play an increasingly important role in the position of a state and its role in the system of international relations.

The lack of infrastructure in less developed countries has allowed some "monopolies" to control the nuclear energy sources and highways of the markets and prices of electricity, gas, coal and oil.

Under these conditions, energy security is no longer just an objective of economic policy, but has become a constant concern for the international community.

Use of nuclear energy resources and electricity as *a pressure tool* or the phrase *energy weapon* is closely linked to the exercise of economic power, an important component in the power complex of a state.

Definition: The energy pressure tool can be defined as any action or inaction of a nuclear energy chain actor *Resources management* (uranium ore) – *Exploiter, Processor and Refining resource* (uranium ore) – *Manufacturer of nuclear fuel beams – Nuclear electricity producer - Storage of radioactive waste – Producer or Stockpile of heavy water* directly or indirectly linked to nuclear energy resources, nuclear fuel or heavy water, which is intended to influence the behaviour of other actors, control or eliminate them, in order to achieve their own interests.

The principle scheme of using nuclear energy resources, nuclear fuels or heavy water as a pressure instrument is shown in Figure 4.

The pressure tool can be used throughout the chain by any of the "links" involved in the process (Fîță et al., 2021).

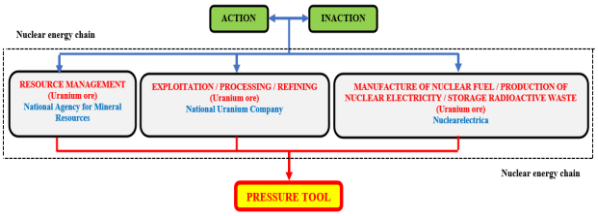

Fig. 4. Schematic diagram of the use of nuclear energy resources, nuclear fuels and heavy water at pressure tool

Conclusions

Since uranium ore and heavy water resources are safety and security elements for those who own them, they can generate energy conflicts or wars, which is characterised by the use of energy instruments to counter the adversary from changing its policy or behaviour, or to undermine the capacity of that state to maintain normal relations with other states in times of peace or war.

Without the resources of uranium ore and heavy water, the national economy can suffer as nuclear power production is halted, bringing immense damage to the national industry and energy security, and for this reason energy security becomes an important component of the national security and foreign policy strategy.

Uranium ore resources and heavy water can be used as political pressure tools or energy weapon for the purpose of profitability and blackmail.

We have identified the following elements generating insecurity and instability (six major challenges):

- *short circuits of supply flows;*
- *the finite nature of energy resources;*
- *use of energy as a pressure tool;*
- *the use of energy revenues to support undemocratic regimes;*
- *global climate change;*
- *high energy costs for developing countries.*

References

Bahnareanu, C. (2008). *Securitate energetică, Centrul de Studii Strategice de Apărare și Securitate, Editura Universitatea Națională de Apărare "Carol I"*. București (in Romanian with an English abstract) Energy Security, Defence and Security Strategic Studies Centre, "Carol I" National Defence University Publishing House, Bucharest

Baumann, F. (2008). Energy security as multidimensional concept. *CAP Policy Analysis*, 1,. 1-14. http://www.cap.lmu.de/download/2008/CAP-Policy-Analysis-2008-01.pdf

Bian, Q., Han, Z., Veuthey, J., & Ma, B. (2021). Risk perceptions of nuclear energy, climate change, and earthquake: How are they correlated and differentiated by ideologies? *Climate Risk Management*, 32, 100297, https://doi.org/10.1016/j.crm.2021.100297

BP Statistical Review of World Energy (Ed.) (2018.) *BP Statistical Review of World Energy 2018* 67 edition, BP p.l.c, (pp. 31-44) https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2018-full-report.pdf

Fîță, N. D., Radu, S. M., Păculescu, D. (2021). *Asigurarea, controlul și stabilitatea securității energetice în context de creștere a securității industriale și naționale – compendiu academic*. Editura Universitas Petroşani, ISBN 978-973-741-743-5, (In Romanian) Ensuring, Controlling and Stability of Energy Security in the Context of Increasing Industrial and National Security – Academic Compendium, Universitas Publishing House - Petroşani .

Ministry of Energy (2016). *Romania Energy Strategy 2016-2030 with Perspective 2050*, 2016, 64 pp. (in Romanian), Summary in English https://energie.gov.ro/wp-content/uploads/ 2016/11 /Romanian-Energy-Strategy-2016-2030-executive-summary3-1.pdf

World Nuclear Association (2018). *Nuclear Energy in the 21st Century* (4th ed.) https://www.world-nuclear.org/shop/products/nuclear-energy-in-the-21st-century-4th-edition.aspx

World Nuclear Association (2020.) *The World Nuclear Supply Chain: Outlook 2040*, https://www.world-nuclear.org/shop/products/the-world-nuclear-supply-chain-outlook-2040.aspx

World Nuclear Association (2021). *The Nuclear Fuel Report: Global Scenarios for Demand and Supply Availability 2021-2040*, (20th ed.) https://www.world-nuclear.org/shop/products/the-nuclear-fuel-report-global-scenarios-2021.aspx

Wu Y., Chen Z., Wang Z., Chen, S., Ge, D., Chen, C., Jia, J., Li, Y., Jin, M., Zhou, T., Wang, F., & Hu. L. **(**2019). Nuclear safety in the unexpected second nuclear era**,** *Proceedings of the National Academy of Sciences - USA,* _ 116(36): 17673–17682. doi: 10.1073/pnas.1820007116