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UDC 338.246.025.13:553.04(73)
338.246.025.13:553.04(4-6EU)
338.32:553.493.34(497.11)
338.24:502.131.1(497.11)
Original scientific article
Received: 09.12.2024.
Accepted: 17.12.2024.
doi: 10.5937/napredak5-55291

Critical mineral resources – lithium (Li)

Abstract: This paper analyzes the concepts and methodologies used by the USA and the EU for establishing the list of critical raw materials (CRM). Critical raw materials as key elements for national security and economy play an important role in energy, industrial and military technologies. The USA has adopted the methodology based on economic vulnerability, disruption potential, trade exposure and supply risk, while the EU uses the criteria of economic importance and supply risk. The CRM lists in the USA and the EU are regularly updated so that the USA included 50 raw materials in its 2023 list, while the EU has 34 raw materials in its list. This paper also considers the importance of lithium as one of the key raw materials at the global level and gives a review of large lithium producers and suppliers, as well as Serbia's potential in this field. Lithium is particularly important for the production of batteries, electronics and space technologies.

Keywords: critical raw materials, US and EU methodology, raw materials of Serbia, lithium, global market, economic and technological aspects

Introduction

The main burning topics worldwide have been analyzed referring to what critical raw materials are, to the manner of determining the critical status of a particular raw material and to the methodology used for determining this status. The main features have been presented of the Critical Raw Materials Act adopted by the EU. The second part deals with the problems related to lithium as one of the most important raw materials from the list of critical raw materials, as well as with the projection of its effect on Serbia's economy.

The term critical raw materials (hereinafter: CRM) was established as a political, geostrategic and military term, and not as a technical or geological one. This term was not used several years ago, but there were only descriptive reports about the

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problems related to certain raw materials and the need of Western economics to ensure the supply of these raw materials. It can be concluded from numerous published expert papers and analyses by the geological institutes of the USA, Canada and EU institutions dealing with the problems of geology, mining and trade in raw materials (metals, non-metals, natural and other materials). Lithium is one of important materials or raw materials from the CRM group and it is included in all lists (the USA, the EU, Australia, Canada, India, Norway...). Lithium is used for different purposes: n non-rechargeable batteries as an anode, in the electrolyte and cathode of lithium-ion rechargeable batteries, lithium-based greases, aluminium production, air purification, in space technology, glass industry, ceramics, foundry industry (iron and steel castings), for special types of rubber and plastic.

Critical raw materials

Currently, there are two widespread methodologies: the US one from 2020 and the European one from 2022. Based on these methodologies, CRM lists have been established in the USA and the EU respectively.

Essentially, there is no definition of critical raw materials. There are several versions given/provided by some countries and organizations which deal in detail with this issue, such as the USA, the EU, Australia and Norway. A general definition of CRM describes them as *minerals*, *elements*, *substances* or *materials* of essential importance for economic or national security of a country, whose supply chain is subject to disruptions. These materials are used in energy technologies, defiance, currency, agriculture, consumer electronics and applications related to health protection, while their shortage may threaten national security and safety of a country.

The US methodology is based on the following factors: *economic vulnerability*, *disruption potential*, *trade exposure* and *supply risk*, with all the parameters being between 0 and 1 (Nassar & Fortier, 2021, p. 3). Based on these factors, the USA (USGS), established the methodology and list of CRM in 2020, which was acknowledged in the Energy Act (U. S. Department of Energy). The 2023 CRM list in the USA contains 50 raw materials: aluminium, antimony, arsenic, barite, beryllium, bismuth, cerium, cesium, chromium, tin, cobalt, dysprosium, erbium, europium, fluorite, gadolinium, gallium, germanium, graphite, hafnium, holmium, indium, iridium, lanthanum, lithium, lutetium, magnesium, manganese, neodymium, nickel, niobium, palladium, platinum, praseodymium, rhodium, rubidium, ruthenium, samarium, scandium, tantalum, tellurium, terbium, thulium, titanium, vanadium, wolfram, ytterbium, yttrium, zinc and zirconium.

The EU established its methodology of determining the CRM list in 2020, but it adopted the CRM Act as late as 2024, obliging all the EU member-states to harmonize their respective legislations in the field of mining and related fields with this Act (Blengini et al., 2017, pp. 1–30). The EU methodology uses the following criteria for establishing CRM – *economic importance* (EI ≥ 2,8) and *supply risk* (SR ≥ 1). The EU list encompasses

34 raw materials. The European list contains the labels L&HREE, RE and PGE, which includes more than 20 special raw materials. The European list encompasses: aluminium/bauxite, antimony, arsenic, barite, beryllium, *boron/borates*, *fluorite*, *phosphate rocks* (*from apatite*), *phosphates* (*phosphorites*), *feldspars*, gallium, germanium, *natural graphite*, hafnium, helium, L&HREE, *silicon metal*, cobalt, *coking coal*, lithium, *magnesium*, manganese, niobium, PGE, scandium, strontium, tantalum, titanium, vanadium, bismuth, wolfram.

LREE is a label for Light Rare Earth Elements – lanthanides group: cerium, lanthanum, neodymium, praseodymium and samarium.

HREE is a label for Heavy Rare Earth Elements – lanthanides group: dysprosium, erbium, europium, gadolinium, holmium, lutetium, terbium, thulium, ytterbium, yttrium.

RE is a label for a group of Rare Elements: niobium, tantalum, strontium, zirconium, hafnium, scandium, rhenium, thallium, gallium, cadmium, indium, selenium, tellurium, germanium.

PGE is a label for a platinum group of elements: platinum, palladium, iridium, osmium, rhodium, ruthenium.

Strategic CRM (the EU): boron, gallium, germanium, natural graphite, L & HREE, silicon metal, cobalt, lithium, magnesium, manganese, PGE, titanium, bismuth, wolfram (copper, nickel).

In both methodologies there is a rule that a new list should be established every three years. The first lists were published in 2020, and the last ones in 2023. (Grohol & Veeh, 2023, p. 3). As it can be seen, many mineral resources are present in both lists. Besides these lists, independently of each other, in the past few years the USA has established a separate CRM list in energy. This list includes only some of the raw materials from the main list. After 2022, the EU established a special list called Strategic Critical Raw Materials. That list includes only some of the raw materials from the European list.

The main elements of the CRM Act adopted by the EU (the EC) are as follows:

1. Minimum 10% of the EU's needs for raw materials should be provided from primary production (mining) in the EU territory;
2. Minimum 40% critical raw materials processing should take place in the EU territory;
3. Minimum 15% of the European needs for critical raw materials should come from recycling;
4. Imports of individual CRM from one country should not exceed 65%;
5. Strategic projects aimed at ensuring critical raw materials should have a quick and simple path towards obtaining exploration and mining permits;
6. It is necessary to enable the priority of such projects in terms of financing;
7. Substantial involvement of the EU and support in the realization of such projects;
8. Activation and exploitation of the mines containing critical raw materials even when initiating production has no economic justification;
9. Establishment of monitoring over critical raw materials, defining supply chains

and predicting potential disruptions in the routes and methods of supply;

10. Including national and commercial banks in these processes on a larger scale;
11. Buyers' association in conglomerates with the main purpose of supplying the EU with critical raw materials more quickly and safely;
12. Data exchange among member-states about active locations of mining and flotation waste landfills;
13. Formation of data bases about old mining locations and places where mining and flotation waste is disposed of;
14. Introduction of magnet recycling as a priority.

The largest world producers of CRM are: China (59%), the USA (7%), South Africa (5%), Australia (4%), Chile (4%), Canada (3%), DR Congo (3%), Turkey (3%), Brazil – France – Greece – India – Indonesia – Mexico – Portugal – Russia – Spain – Thailand (1%).

The largest world exporters of CRM are: China: barite (38%), bismuth (49%), cerium (99%), dysprosium (98%), erbium (98%), europium (98%), gadolinium (98%), holmium (98%), thulium (98%), lutetium (98%), ytterbium (98%), lanthanides (99%), magnesium (93%), graphite (47%), neodymium (99%), praseodymium (99%), samarium (99%), terbium (98%), titanium (45%), wolfram (26%), yttrium (98%).

Africa: bauxite (64%), cobalt (68%), phosphate rocks (24%), tantalum (36%).

South America: fluorite (25%), lithium (78%), niobium (85%).

Asia: natural rubber (31%), phosphates (71%).

Australia: coking coal (24%) (Blengini et al., 2020, p. 9).

Serbia, mineral resources and critical raw materials

In the territory of Serbia, exploration and exploitation of raw materials in recent history have lasted uninterruptedly since 1835. That is when Baron Sigmund August Wolfgang Herder came to Serbia at the invitation of Prince Miloš, in order to "make use of the mining wealth for the sake of Serbian fatherland". At the end of 1848, exploration works and iron exploitation began in Majdanpek, Rudna Glava and Crnajka. To date, the following raw materials have been explored in our country, from the level of ore occurrences to deposits:

Metallic raw materials: lead-zinc, copper, gold, antimony, tin, iron, manganese, wolfram, chromium, nickel-cobalt, molybdenum, bauxite, mercury, REE, PGE, lithium, bismuth, titanium (Geodetic Institute, group of authors, 1999, pp. 1–240; Jelenković, Mijatović, 2006–2010).

Non-metallic raw materials: magnesite, dunite, chrysotile asbestos, refractory/ceramic/ kaolin clays, aluminosilicates, feldspars, quartz sand, quartz raw materials, bentonites, zeolite, diatomites, limestone, dolomite, barite, fluorite, boron, phosphorite, anhydrite, talcum, wollastonite, vermiculite, micas, jewellery raw materials, graphite (Geodetic Institute, group of authors, 1999, pp. 1–240; Jelenković, Mijatović, 2006–2010).

Energy raw materials: coals (stone, brown, lignite), oil shales, *uranium*, oil and gas (Geodetic Institute, group of authors, 1999, pp. 1–240; Jelenković, Mijatović, 2006–2010).

From this short review, it can be clearly seen that the geological explorations to date have registered numerous mineral resources which are nowadays treated as CRM in Europe and worldwide. According to the EU methodology and list of CRM, the following raw materials have been registered in Serbia: *copper*, *antimony*, *manganese*, *wolfram*, *nickel-cobalt*, *titanium*, *bauxite*, *L&HREE*, *PGE*, *lithium*, *magnesite*, *feldspars*, *barite*, *fluorite*, *boron*, *phosphorite*, *graphite*, *arsenic*, *bismuth*.

In technogenic/secondary deposits (tailings), after processing lead-zinc and copper ores, significant content of the following elements has been registered: *scandium*, *indium*, *gallium* (RE), *L & HREE*.

Global demand for CRM and other metals by materials for pure energy technologies according to STEPS and SDS scenario

According to STEPS, the current assessment (STEPS) of the EU's needs for metallic raw materials until 2050 is 45 million tons. According to the dynamic assessment of the needs for metallic raw materials (SDS) in the EU (aluminium, copper, nickel, zinc, lead, silicon, lithium, manganese, chromium, cobalt ...) until 2050 is 75 million tons. The OECD assessment shows that the global demand for raw materials will increase from the current amount of 79 million tons to 167 million tons until 2060.

The assessment of the percentage increase in the needs for metals until 2050 for pure energy technologies as compared to the general use in 2020 (global SDS ambitious climate scenario) is as follows (CRM + other metals):

Table 1. Assessment of the percentage increase in the needs for metals until 2050

Raw material	Percentage increase	Raw material	Percentage increase
Lithium (Li)	2.109%	Silicon (Si)	62%
Dysprosium (Dy)	433%	Terbium (Tb)	62%
Cobalt (Co)	403%	Copper (Cu)	51%
Tellurium (Te)	277%	Aluminium (Al)	43%
Scandium (Sc)	204%	Tin (Sn)	28%
Nickel (Ni)	168%	Germanium (Ge)	24%
Praseodymium (Pr)	110%	Molybdenum (Mo)	22%
Gallium (Ga)	77%	Lead (Pb)	22%
Neodymium (Nd)	66%	Indium (In)	17%
Platinum (Pt)	64%	Zinc (Zn)	14%
Iridium (Ir)	63%	Silver (Ag)	10%

Source: KU Leuven, 2022: Metals for clean energy: Pathways to solving Europe's raw materials challenge

The assessment of the increasing demand in the EU for metals necessary in the development of pure energy technologies:

Table 2. Electric vehicles (without batteries and permanent magnets)

Demand (kt)		Base metals	Other metals
In 2020	In 2050	Al, Cu, Pb, Zn, Si	B, Ag, Ga, Pt, Au, Ge, In
482	5.356		

Source: KU Leuven, 2022: Metals for clean energy: Pathways to solving Europe's raw materials challenge

Table 3. Batteries for electric vehicles

Demand (kt)		Base metals	Other metals
In 2020	In 2050	Ni, Li, Si, Co, Mn	Al, Cu
34	1.287		

Source: KU Leuven, 2022: Metals for clean energy: Pathways to solving Europe's raw materials

Table 4. Solar panels (photovoltaic)

Demand (kt)		Base metals	Other metals
In 2020	In 2050	Al, Zn, Cu, Si	Sn, Pb, Ag, Ni, Te, Cd, In, Ga, Ge
0	697		

Source: KU Leuven, 2022: Metals for clean energy: Pathways to solving Europe's raw materials challenge

Table 5. Wind turbines

Demand (kt)		Base metals	Other metals
In 2020	In 2050	Cu, Al, Mn, Cr, Ni	Zn, Mo, B
75	206		

Source: KU Leuven, 2022: Metals for clean energy: Pathways to solving Europe's raw materials challenge

Table 6. Hydrogen (technologies)

Demand (kt)		Base metals	Other metals
In 2020	In 2050	Ni, Cu, Cr, Al, Zn	Mn, Sc, Co, Ir, Pt
0	3,95		

Source: KU Leuven, 2022: Metals for clean energy: Pathways to solving Europe's raw materials challenge

Table 7. Permanent magnets

Demand (kt)		Base metals	Other metals
In 2020	In 2050	Nd, Pr, Dy	Tb
0	2,67		

Source: KU Leuven, 2022: Metals for clean energy: Pathways to solving Europe's raw materials challenge

Table 8. Electric power grid

Demand (kt)		Base metals	Other metals
In 2020	In 2050	Al, Cu, Zn	
297	511		

Source: KU Leuven, 2022: Metals for clean energy: Pathways to solving Europe's raw materials challenge

Lithium

Lithium (Greek Λίθος – stone) has symbol Li and atomic number 3 on Mendeleev's Periodic Table, while it is the lightest of all known metals. Its atomic weight is 6.94 and specific density 0.534 g/cm^3 (at the temperature of 20°C).

It is composed of two lithium isotopes – ^{7}Li (92.6%) and ^{6}Li (7.4%) and belongs to the group of alkali metals. Lithium is a very light metal and has the lowest density of all solid elements (in standard conditions).

The history of lithium began around 1800, when famous Brazilian statesman, geologist, natural scientist and poet José Bonifácio de Andrada e Silva discovered and described the mineral petalite (LiAlSi4O10) in the rock samples from the island of Utö, Sweden. Lithium was discovered by Johan Arfwedson in 1817. Berzelius, his university mentor, suggested the name for the new material – lithion. Many years later, pure lithium was obtained by the lithium-oxide electrolysis procedure, while larger amounts of lithium were obtained from lithium-chlorine in the middle of the 19th century. Intensive lithium production began in Germany in 1923 through the electrolysis of molten mixture of lithium chloride (LiCl) and potassium chloride (KCl). Until the end of the Second World War, lithium was used solely as a machine lubricant and in glass industry. Real expansion of the demand for lithium occurred in the USA after the Second World War. That is when the US scientists working on the development and improvement of the hydrogen bomb, while looking for tritium, managed to obtain it by separating it from lithium through ^{6}Li neutron activation in the nuclear reactor.

Due to its geochemical characteristics and great reactivity, lithium is found in its elementary state in nature. When in its elementary state, it is kept in kerosene or some other mineral oil. In dry air it becomes lithium nitride, while in damp air it turns into lithium hydroxide. In the form of various salts, it is found in mineral waters.

In nature, lithium participates in the building of a series of minerals. Some of them are base ores in the processing of which lithium carbonate is obtained, as follows:

- spodumene,
- petalite,
- lepidolite,
- zinnwaldite,
- amblygonite,
- jadarite,
- hectorite,
- zabuyelite.

The main source of lithium from rocks is the mineral spodumene from the group of pyroxenes, built from lithium inosilicate. Essentially, it is a petrogenic mineral which builds different types of rocks, including pegmatites. In the course of lithium exploitation from pegmatites, first a spodumene concentrate is obtained, and then, in the technological procedure, lithium carbonate is obtained. Spodumene in pegmatites is found together with the minerals with lithium, such as petalite and amblygonite, but they are largely subordinate.

A special type of the mineral lithium is zabuyelite, which is a natural lithium carbonate (not artificially produced). It was discovered in 1987 in

Tibet – in Lake Zabuye, after which it was named, while its exploitation began in 2004/2005.

Particularly outstanding in the list of minerals from which lithium is obtained are jadarite and hectorite. Apart from jadarite, hectorite and zabuyelite, above-listed minerals are present in the composition of pegmatites as petrogenic minerals, while pegmatites are the final phases of differentiation and solidification of granitic melt when there is an increased content of water enriched with fluorine and lithium. Jadarite is a new mineral discovered in the samples from the exploration wells in the Jadar River Valley near Loznica, in the layers of ore body drilled in 2004. Since 2004 to date, the same mineral

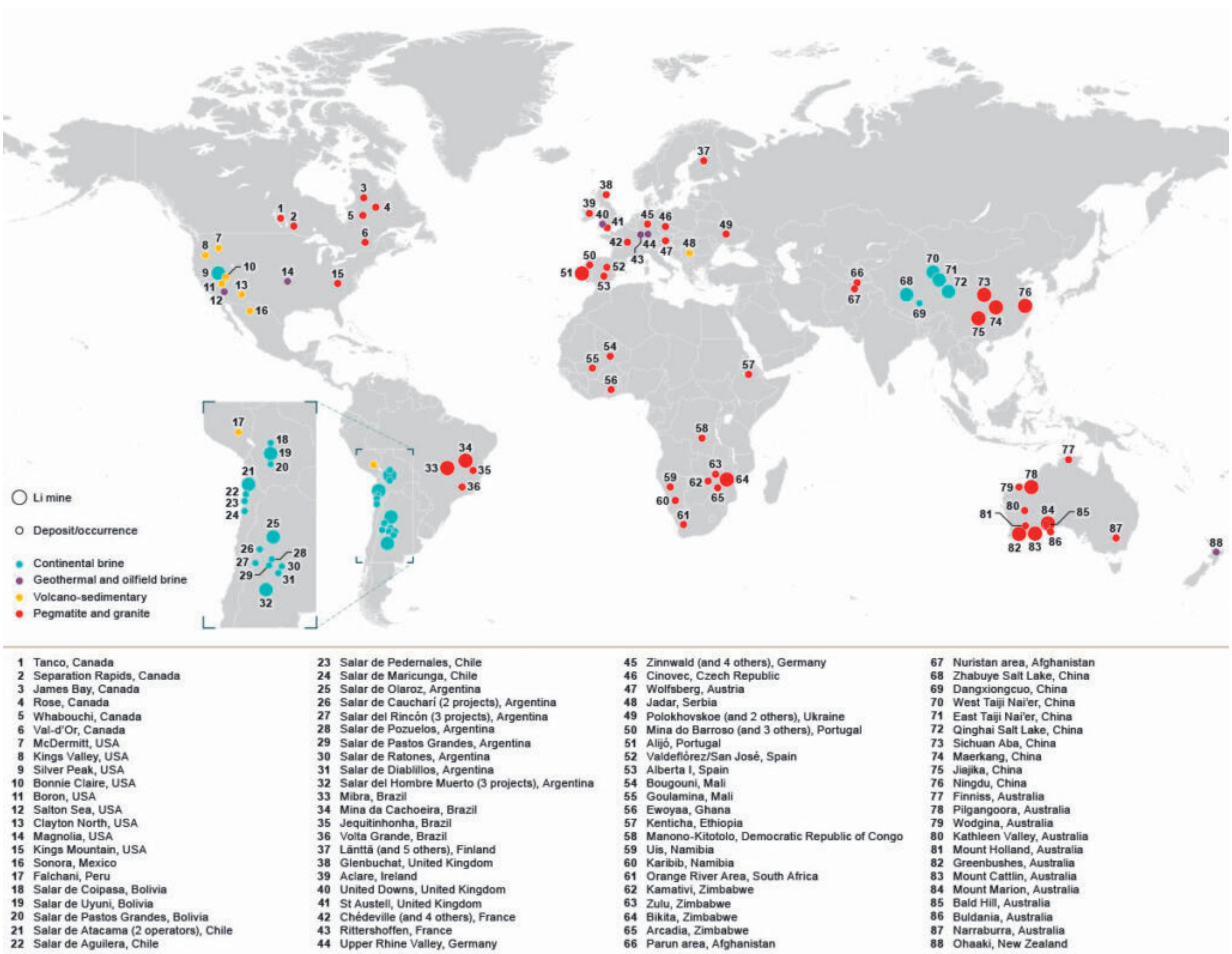

Figure 1. Map of the distribution of lithium mines, deposits and occurrences in the world
Source: Shaw, 2021

has not been registered anywhere else in the world. The mineral hectorite is the main component of white greasy clays created by the decomposition of granitoids (rhyolite pegmatites). Future exploitation of lithium from the mineral zinnwaldite, is planned in the Federal Republic of Germany. Zinnwaldite is a silicate mineral from the group of micas, and by its composition it is potassium-lithium-iron-aluminium-silicate-hydroxide fluoride. Lepidolite is also a silicate mineral and a secondary source of lithium, occurring together with spodumene. It is of greatest importance for the production of rubidium.

Lithium exploration is in full swing throughout the world – in Australia, China, the USA, Argentina, Chile, Bolivia, Portugal, Germany, Czech Republic, Finland, Great Britain, France, Norway, India and Serbia. There are several reasons for geological exploration of lithium: first, the lack of lithium in the market (demand greater than offer), then the development of new technologies, implementation of agendas for "green energy" and "decarbonization", wide application in different branches of industry, and categorizing lithium among CRM.

In November 2021, BGS presented the world map with the list of all the lithium deposits and occurrences (Shaw, 2021). The list contains 88 locations/toponyms with different statuses: occurrences currently explored, deposits with completed explorations and without exploitation, and deposits in the process of exploitation.

The distribution by continents is as follows:

- **North America:** 15 locations are shown, whereas only lithium is exploited in just one location. In the deposit in Silver Peak (the USA) lithium is obtained from salt solutions by pumping about four billion gallons of water (US gallon = 3.785 l) from the underground, or 15.14 billion litres of water, every year since 2020. The annual production is about 6,800 t of lithium. In other locations, either intensive exploration is performed or lithium is just one of the raw materials being exploited (Nb, Ta and others).
- **Central America:** The project Sonora is under development in Mexico, and there are no other projects.
- **South America:** 20 locations are being actively explored. Four deposits are exploited from salt groundwater and two deposits are exploited from pegmatites. Lithium is exploited from salt water in Saler de Uyunu – Bolivia, Saler de Atacama – Chile, Saler de Olaroz – Argentina, and Saler de Hombre Muerto – Argentina. Lithium is exploited through surface exploitation of pegmatites in Mibra – Brazil and, apart from lithium, tantalum and niobium are also obtained. In the underground exploitation of spodumene, lithium is exploited from pegmatites in Mina da Cachoeira, Brazil.
- **Africa:** lithium is explored at 12 locations, while surface exploitation is performed in the mine Bikita – Zimbabwe, where spodumene and petalite are exploited and lithium is obtained from them.
- **Asia:** intensive exploration at three locations. Exploitation is performed in four places from salt groundwater and in four places from pegmatites. Exploitation from salt water is performed in several salt lakes in China: Zabuye Salt Lake, West Taiji Nai'er, East Taiji Nai'er and Qinghai Salt Lake. Exploitation from pegmatite is performed at four locations in China: Sichuan Abe, Maerkang (surface exploitation from pegmatites – spodumene), Jiajika (surface exploitation from albite-spodumene

pegmatites with lithium, while beryllium, niobium, tantalum and cesium(caesium), Ningdu (open pit granite-pegmatite mine) are also obtained.

- **Australia:** there are four active mines with surface exploitation. The active mines are: Pilgangoora (surface open-mine in pegmatites, where lepidolite, spodumene, tantalite, cassiterite and small amounts of microlith, tapiolite and beryl are exploited; Li + Ta products), Greenbushes (open-pit mine of pegmatite with spodumene, the biggest world mine of Li in pegmatites), Mount Cattlin (open-pit mine, pegmatites with spodumene), Mount Marion (open-pit mine, pegmatites with spodumene).

In Europe, lithium is exploited only in one place – form the deposit Alijo in Portugal, from the mineral spodumene. There is intensive geological exploration of all raw materials from the CRM list in Europe. Out of numerous locations in Europe where lithium is explored, the exploration is in its final phases at 21 locations. Exploration works and accompanying studies have progressed furthest at the following locations:

- *Mines in the exploration phase*: Goncalo – Alvaroso, Bajoca – La Fregeneda, Goncalo – Castanho, all the locations in Portugal (Filippov, Filippova, 2023);
- *Projects in development (feasibility study preparation)*: Central Ostrobothnia (Keliber) – Finland, Zinnwald – Germany (Filippov, Filippova, 2023);
- *Projects with a feasibility study*: Cinovec – Czech Republic, Wolfsberg – Austria, Mina do Barroso, Romano Sepeda, Argemela – Portugal, San Jose – Spain, Emili – France (Filippov, Filippova, 2023), Serbia – Jadar (Faculty of Mining and Geology, 2021);
- *Projects in the pre-feasibility study phase*: Sadisdorf – Germany, Presqueiras – Spain (Filippov, Filippova, 2023);
- *Projects attractive for continued research/work*: Adagoi, Alijo – Portugal, Hirvikallio, Kietyönmäki – Finland, Bergby, Varuträsk – Sweden, NW Leinster – Ireland (Filippov, Filippova, 2023);

The European Union has directly supported the following projects: Goncalo-Alvaroso, Mina do Barroso – Portugal, Central Ostrobothnia (Keliber) – Finland, Emili – France (Filippov, Filippova, 2023).

The largest lithium (metal) reserves in the world are located in the following countries:

1. Bolivia – 23 million tons,
2. Argentina – 22 million tons,
3. Chile – 11 million tons,
4. Australia – 8.7 million tons,
5. China – 6.8 million tons,
6. Germany – 3.8 million tons,
7. DR Congo – 3 million tons,
8. Canada – 3 million tons,
9. Mexico – 1.7 million tons,
10. Czech Republic – 1.3 million tons,
11. *Serbia – 1.2 million tons*,
12. Peru – one million tons,
13. Russia – one million tons,
14. Mali – 890,000 tons,
15. Brazil – 800,000 tons,
16. Zimbabwe – 690,000 tons,
17. Spain – 320,000 tons,
18. Portugal – 270,000 tons,

19. Namibia – 230,000 tons,
20. Ghana – 200,000 tons,
21. Finland – 68,000 tons,
22. Austria – 60,000 tons,
23. Kazakhstan – 50,000 tons (USGS, 2024).

Today, lithium is obtained on the largest scale by exploitation from continental highly-mineralized salt waters (Chile, Argentina, Bolivia, China, the USA); then by processing minerals spodumene and lepidolite (with the accompanying pegmatite minerals). Very small amounts, in the experimental phase, are obtained from hectorite in Cornwall, partly also within the future deposit in McDermitt, USA. In the near future, after the completion of exploration and the beginning of exploitation, lithium will also be obtained from geothermal waters and salt waters in oil drills (Magnolia in the USA, the Rhine River valley in Germany, United Downs in the UK), from volcanogenic-sedimentary deposits (Jadar in Serbia; McDermitt, Kings Valley, Bonnie Claire, Boron, Clayton North, Kings Mountain in the USA, and Falchani in Peru). With the beginning of exploitation in the Czech Republic (Cinovec) and Germany (Zinnwald) lithium carbonate will be obtained from the mineral zinnwaldite. Only in China natural lithium carbonate is exploited from the salt lake waters in Tibet in the form of the mineral zabuyelite.

The biggest world producers of lithium in the period 2021–2023 are shown in Table 9.

Table 9. Lithium production in the world

Producing countries	Production in the world (t)		
	In 2021	In 2022	In 2023
Australia	55,000	61,000	86,000
Chile	28,300	39,000	44,000
China	14,000	19,000	33,000
Argentina	5,970	6,200	9,600
Brazil	1,700	2,200	4,900
Zimbabwe	710	800	3,400
Canada	/	500	3,400
Portugal	900	600	380
Other countries	/	/	3,700

Source: STATISTA; USGS, 2024

Three biggest world producers of lithium carbonate and lithium hydroxide are Australia, Chile and China, which cover 90% of the world's market, while Argentina, Brazil, Zimbabwe, Portugal and Canada account for 9.5%, and all other countries having the remaining share in the world's production. The biggest producer of lithium in Europe is Portugal.

Generally speaking, according to the statistical data, lithium production in 2023 amounted to about 188,000 t, while the world-level demand was about 980,000 t. In 2025, lithium demand will exceed one million tons, and by 2030 it will exceed two million tons. At the same time, it is estimated that lithium production in 2025 will reach the amount of about 500,000 t, which can by no means fulfil the needs of world economy. The needs for lithium will continue to increase and in 2050 demand for this metal will reach about 3,500,000 t (all data have been taken from German specialized website STATISTA). The discrepancy between lithium offer and demand is not surprising when we take into account its multiple uses: batteries – 87%; ceramics and glass – 4%; lubricants – 2%; air treatment – 1%; flux powders for continual flux powders for continuous casting moulds – 1%; medicine – 1%; and other uses (production of aluminium, special types of rubber, pharmacy, cosmetics, electronics) – 4%.

The growing lithium market has been accompanied by the instability of its price in the past two years. After the significant increase at the beginning of 2022, the price of lithium began fluctuating due to the changes in stock. In 2022, the supplies of lithium-based products which were necessary for battery production were reduced, but in 2023 they began increasing, both due to the growing offer of the existing producers, and due to the new participants in their production. One of the reasons for the decrease in the lithium prices in the world's market is also the discontinuation of government subsidies in 2022 in PR China and FR Germany for the purchase of electric vehicles. The trends of lithium prices at the world level and their projection until 2030 are shown in the following figure:

Year	Price range projection	Key factors
2024	LITHIUM HYDROXIDE: $12.775 LITHIUM CARBONATE: $9.856,55 TO $15.500	• INCREASING ACCEPTANCE OF ELECTRIC VEHICLES • SLOWER SALE OF ELECTRIC VEHICLES • BATTERY CAPACITY SURPLUS IN CHINA
2025	LITHIUM HYDROXIDE: $13.485/T LITHIUM CARBONATE: $9.411,15/T TO $20.000/T	• CONSTANT EXCESSIVE SUPPLY • INCREASING DEMAND FOR ELECTRIC VEHICLES • USA AND CHINA TRADE WAR
2026-2030	LITHIUM HYDROXIDE: 2026: $14.775 LITHIUM CARBONATE: 2026: $12.000 2027: $14.000	• ENERGY TRANSITION • DEMAND EXCEEDS SUPPLY • APPEARANCE OF ALTERNATIVE BATTERY SOURCES

Figure 2. Comparative projection of the price of lithium hydroxide and lithium carbonate

Source: Techopedia

It is predicted that the prices of raw materials for the production of batteries will remain higher because of the expected offer growth, challenges and costs related to production etc. Most capacities for lithium exploitation were concentrated in Chilean salt pans and lithium hard-rock deposits in Australia (spodumene mines). China has a dominant position in the processing of lithium ore.

Average prices of lithium carbonate, lithium hydroxide and spodumene today as compared to January 2024 are as follows:

- lithium carbonate – US$ 10,934 per ton (January: US$ 11.867);
- lithium hydroxide – US$ 9,563 per ton (January: US$ 9.899)
- spodumene – US$ 990 per ton (January: US$ 1,000)

According to the data of the company Rio Sava (Elaborate on the reserves from 2020), the production of jadarite ore from the deposits should be maintained at 1.8 Mt/g, while the production of lithium carbonate should be maintained at 58,000 t/g

(Misailović, Tanasković, 2020). When this is compared with the production from the previous table, Serbia would have the second place in the world by the production of lithium carbonate. From the quantity of proven reserves, only the jadarite deposit belongs to the category of large deposits. Proven reserves are 158,647,256 tons. The exploitation period is predicted to be longer than 60 years. After analyzing the available data about the planned activities in geology and mining in the EU territory, future exploitation of lithium from European deposits, market needs and investments in industry using lithium, and exploitation plans, it can be concluded that Serbia will be at the very top of European exploitation of lithium ore and lithium-based industry. According to the predicted production, as it has already been stated, Rio Sava is planning the annual production of 58,000 tons of lithium carbonate. The estimates of the future production of LCE (lithium carbonate equivalent) in Europe are presented in the following table:

Table 10. Predicted production of lithium carbonate in the EU

No.	Producing country	Lithium carbonate (t)
1.	Serbia	58.000
2.	Germany	42.000
3.	Czech Republic	30.000
4.	UK	28.000
5.	Portugal	20.000
6.	Finland	20.000
7.	Spain	15.000
8.	Austria	9.000

The review of price trends per ton of lithium carbonate in the Chinese yuan (1 yuan = US$ 0,14), in the world's market is presented in the following chart:

Chart 1. Price trends of lithium carbonate (2020–2025)

Source: Trading Economics

According to some estimates of the share of LCE from Jadar in the needs of Serbian and European industry using lithium carbonate, Rio Sava would fulfil almost 50% of the needs. This is essentially the assessment of the conditions in the market until 2030, provided that the deposit in the Jadar Valley remains in function. All European and world statistics regarding lithium emphasize great demand for lithium/lithium carbonate, and the production cannot keep pace with such demand. That is why lately intensive geological exploration has been performed and there is an attempt to turn as many exploration projects as possible into exploitation projects. According to the assessments by Western analysts, in order to stabilize the market of lithium/lithium carbonate until 2040, in the period until 2040 it is necessary to open another 60 more lithium mines worldwide which would be of the same size as the Jadar mine,

The assessments have been made of the effects of mine opening and operating in the Jadar Valley for Serbian economy. The first effects would be shown in Rio Tinto's investment in the mine opening project. According to the data from the Elaborate on reserves, the investment in the preparation of underground mining facilities and surface mining infrastructure with the production section intended for obtaining lithium concentrate, boric acid and sodium sulphate, and with the waste treatment system, would amount to about two billion Euros (Misailović, Tanasković, 2020). In the phase of ore exploitation and processing to final products, as many as 2,000 more workers would be employed, both with high qualifications and with no qualifications. This should also take into account the engagement of external service activities outside the mine and processing system. As for the effects regarding Serbia's budget, several options or scenarios have been considered:

1. LCE production and market placement, according to the estimates, would account for only about 0.95% of GDP;
2. Production of LCE and cathodes and their placement in the market, according to the estimates, would account for about 2.06% of GDP;
3. Previous complete production and batteries, according to the estimates, would account for about 3.97% of GDP;
4. Production from previous options and electric vehicles, according to the estimates, would account for about 16.45% of GDP.

If we take into account such development of the situation at the economic level on the one hand, and the intensification of interments into our mining sector (government, domestic and foreign capital) through different forms of investing, on the other hand, GDP might be increased on a large scale. For all this there are real prospects, particularly taking into account the prepared Master Plan for Mining in Serbia, which was financed by the World Bank (Nishikawa, 2008). The Master Plan was prepared by the Japanese company JICA in 2008 and it assessed that mining in Serbia had realistic foundations to participate in GDP with about 16%.

Economic effects of lithium exploitation can be monitored in the following example from Australia. The figure below shows the value of lithium in Australia and in the world after extraction and different levels of processing. The total value of lithium ore accounts only for about 1% of the total value of the end product. Approximately 99.5% of

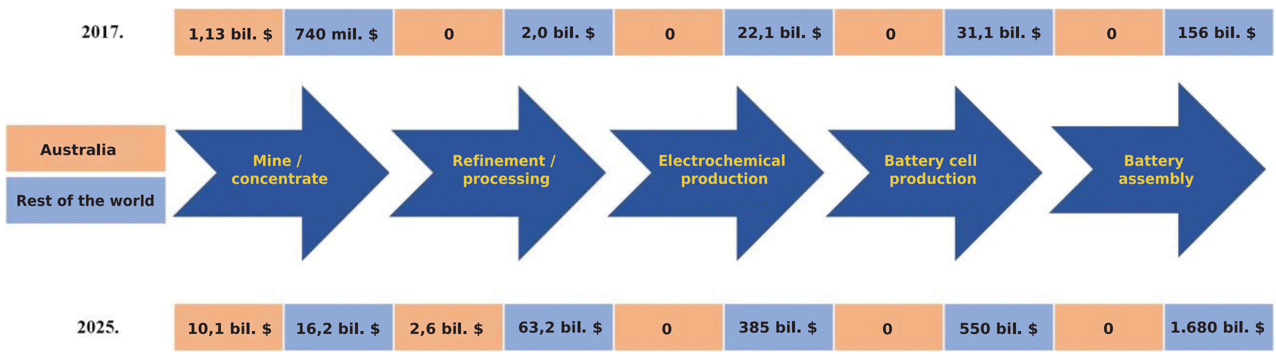

Figure 3. Value of lithium in Australia and the world depending on the degree of refinement and use
Source: Capturing the value of the global lithium supply chain. Innovation Newsnetwork

the value of Australian lithium ore is added through its processing at the sea, through production of cells and assembly of batteries.

Conclusion

The issue of CRM, in particular of lithium as one of very important raw materials from the CRM list, has been dealt with in the main segments in this paper. There is a descriptive definition of CRM and the methodologies on the basis of which they are determined. At the end of the first part of the paper, which deals with CRM, there is an overview of raw materials in Serbia, as well as the list of raw materials explored in Serbia and included in the EU's list of CRM.

The second part of the paper deals with lithium, currently one of the most demanded metals in world's economy. It is necessary in many branches of industry and, at the global level, there is a huge demand for its main product - lithium carbonate, which has multiple application. Currently, the demand for lithium substantially exceeds its offer in the market. That is the main reason for intense geological explorations by the most powerful mining companies worldwide, i.e., on all continents. On the other hand, many countries in whose territories new deposits can be expected see an opportunity for their economic stability, progress, adoption and development of new technologies.

All CRM from the European list that can be found in Serbia, in particular lithium, are the country's important resource for the development of new technologies aimed at implementing the policy of climate neutrality and decarbonization until 2050, which is defined by the Integrated National Energy and Climate Plan of the Republic of Serbia for the period until 2030, with a vision until 2050.

The final part of the paper presents Serbia's possibilities regarding the development of the mines of jadarite (lithium) in the Jadar Valley and shows potential financial effects on Serbia's GDP.

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