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ENVIRONMENTAL AND ECONOMIC ASSESSMENTS THE EFFECT OF CRITICAL MINERAL OF GREEN REVOLUTION - LITHIUM

Abstract

In this paper, we wanted to explain the phenomenon of economic and environmental effect of the green mineral lithium in the world and our country. We started with an answer to the question why the mineral lithium is the future and support for the green revolution in the world. We have tried to also give a special dimension to tendencies and activities with regard to the usage of green mineral lithium in the world market. In addition, the paper presents the Jadarko project and mineral lithium as economic and environmental opportunity for Serbia.

Keywords: lithium, green revolution, Jadarko project

1 INTRODUCTION

The current world economic crisis and enormous over-exploitation of crude oil and petroleum products indicates the untenable situation in the system of environmental protection and sustainable development. Energy reserves on the planet are drastically reduced and mankind has not found yet a sufficient and adequate substitute for conventional energy generating products. It was this very fact that initiated research with the aim to find the new material and mineral resources replacing the traditional energy sources in order to preserve the environment and sustainable development. This article strives to demonstrate (taking into account that the oil was economic energy source of the 20th century) the environmental and economic assessment the effect of lithium as the green revolution material, and energy of the 21st century.

Lithium was first discovered by the Swedish chemist Johan August Arfwedson, back in 1817.

In this paper, it will be proved that the presence of lithium mineral is so great that it has been used everywhere from glass and ceramics to fat and polymer, and even in medicine. Through the paper it will be studied if there are sufficient reserves of lithium at the global level, but also in Serbia, because it is estimated that it will be used at least until the end of the 21st century up to 2100.

In the era of green revolution, a key role will be taken by the electric cars as a new green phenomenon with plenty of room in many economies in the world. This leads us to an answer to the question whether the lithium reserves today are sufficient to meet demand of electric vehicles using lithium-

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ion batteries in the era of green revolution. A special section will refer to the research of availability and usefulness of this mineral in our country.

2 MINERAL LITHIUM, THE FUTURE AND SUPPORT FOR THE GREEN REVOLUTION

Lithium with a purity of 99.5% as a chemical element in perspective will be in great demand because it is used by the smart phones, electric cars, hybrid cars, and so on. Thus, lithium is used in a wide range of products, from ceramics to the solar cells. Rechargeable batteries and electric batteries provide the most room for growth of lithium compounds. According to a recent study of BMW, depending on the model of battery, in the world, the average use is from 80 to 130 grams of metallic lithium per kilowatt [10]. Consumption of lithium batteries has increased significantly in recent years. Rechargeable lithium batteries are used in smart phones which have 2-3 grams of lithium, laptops from 30 to 40 grams, tablets 20 to 30 grams of lithium, hybrid and electric vehicles from 0.8 to 2 kg of lithium, electric cars which have 10 to 63 kilograms of lithium, Tesla model S electric car has 51 kg of lithium carbonate [12]. It is estimated that demand for lithium will be even greater, from 160,000 tons today to 570,000 tons in 2025[19].

It is an interesting data that by 2040, 50% of demand for the new batteries could be met through recycling the electric batteries for vehicles [21]. The market of electric and hybrid vehicles is growing, from 0.4% in 2012, to 0.7% in 2014, and this is only in the United States. Toyota, the Japanese automaker, has sold eight million hybrid vehicles in the past two decades. In 2015, the Japanese manufacturer Toyota has taken the lead in the lowest CO₂ emissions of 110.1 g/km. Right behind them is Renault - Nissan and Fiat Chrysler.

In the very near future, the EU plans to penalize car owners issuing a fine of 95 euros for every gram of CO₂ above the manufacturer's guideline. The new manufacturer of electric cars Tesla seeks to increase production tenfold, and it is from 50,000 electric vehicles per year presently to half a million vehicles by 2018. It is expected that the electric cars world market will increase up to 100% of the world production of cars by 2025, and these trends indicate the potential rapid growth of the market of lithium batteries for a period of 20-30 years, indicating a momentum of lithium carbonate industry, which is currently still emerging [5]. Thus the industry of electric cars will meet demand for lithium ion batteries in the 21st century (Table 1).

Plans of Norway expressed through demand for sodium batteries just confirm this. Proportionally to the number of 5 million inhabitants, this country has the largest number of electric vehicles. The Government incentives in Norway are very interesting because the all electric cars are exempt from traditional fees and taxes (VAT 25% of the vehicle price without taxes). Oslo, the capital of Norway, in addition to this, has lanes for electric vehicles, privileged parkings for electric vehicles and so on. There are also plans to ban the sale of traditional gasoline engines in Norway by 2025. This economy went a step further, and the trend is towards eco-standards of the EU, so that the vehicles that emit less than 50 g CO₂/km are exempt from the annual taxes. Up to 6,300 US dollars is being allocated for the purchase of commercial electric vehicles in the United Kingdom. Electric cars in China are exempt from excise and purchase taxes based on engine displacement. Incentives for the purchase of electric cars in China are in the range from \$6,000 to \$10,000 USD. In 2016, China announced its plans to build 12,000 stations for electric vehicles providing support for five million electric vehicles by 2020[20].

Table 1 Deutsche Bank forecasts and trends of lithium supply and demand 2015-2025 [14]

Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Country											
Lithium supply (in kt)											
Chile	63	64	65	75	85	100	110	110	110	110	110
% growth	2%	2%	16%	16%	13%	18%	10%	0%	0%	0%	0%
Australia	57	69	97	112	130	159	181	186	196	206	206
% growth	40%	21%	40%	15%	16%	23%	14%	3%	5%	5%	0%
Argentina	19	31	36	41	46	48	69	103	138	153	153
% growth	4%	63%	16%	14%	12%	5%	44%	49%	34%	11%	0%
China	18	23	28	35	35	35	35	35	37	38	43
% growth	-16%	29%	22%	25%	0%	0%	0%	0%	6%	3%	13%
SAD	4.5	4.5	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
% growth	0%	0%	33%	0%	%	0%	0%	0%	0%	0%	0%
Rest of the world	10	10	10	10	10	10	10	10	10	10	30
% growth	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total kt	171	201	242	278	311	358	411	450	497	523	548
% growth	9%	18%	20%	15%	12%	15%	15%	9%	10%	5%	5%
Lithium demand/ (in kt)											
Electric vehicles	25.1	39.7	50.4	68.7	82.4	109.4	128.0	146.9	166.0	185.5	204.8
% growth	152%	58%	27%	36%	20%	33%	17%	15%	13%	12%	10%
Energy storage	0.4	0.7	1.4	2.2	4.3	5.8	7.7	11.1	15.9	23.4	33.8
% growth	0%	62%	96%	57%	92%	36%	32%	45%	43%	47%	45%
Electric bicycles	2.9	7.1	16.9	28.6	41.7	53.6	60.3	67.1	73.8	73.8	73.8
% growth	0%	145%	136%	70%	45%	29%	13%	11%	10%	0%	0%
Glass, ceramics	42.6	44.0	45.7	47.3	49.1	50.9	52.8	54.7	56.8	58.9	61.0
% growth	-3	3%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Batteries (traditional market)	45.6	46.3	48.1	50.2	53.1	55.0	56.4	57.8	59.3	61.0	52.7
% growth	11%	1%	4%	4%	6%	4%	2%	3%	3%	3%	3%
Fat	19.0	19.6	20.3	21.0	21.7	22.5	23.2	23.9	24.7	25.5	26.3
% growth	13%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Air treatment	7.3	7.5	7.8	8.1	8.4	8.7	9.0	9.3	9.7	10.0	10.4
% growth	-9	3%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Polymer	6.2	6.3	6.5	6.7	7.0	7.2	7.3	7.5	7.7	7.9	8.1
% growth	-4	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Medical materials	6.7	6.8	6.9	6.9	7.0	7.1	7.1	7.2	7.3	7.4	7.4
% growth	20%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%

Continuation Table 1

Primary batteries	2.9	3.0	3.1	3.3	3.4	3.5	3.6	3.8	3.9	4.1	4.2
% growth	-8%	3%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Aluminium	2.5	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5
% growth	26%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%
Casting powders	7.6	7.6	7.8	7.9	8.0	8.1	8.3	8.4	8.5	8.7	8.8
% growth	-21	1%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Others	15.0	18.0	20.7	22.8	23.6	24.5	25.4	26.3	27.3	28.3	29.4
% growth	63%	20%	15%	10%	4%	4%	4%	4%	4%	4%	4%
Total (kt)	184	209	238	277	312	359	392	427	464	498	534
% growth	18%	14%	14%	16%	13%	15%	9%	9%	9%	7%	7%
Market surplus (deficit)	-13	-8	3	1	-2	-2	19	22	33	25	14

The State of California in the USA offers \$2500 USD incentives for purchase of electric vehicles (the US average is \$1000). Over the next two decades, demand for gasoline in the United States will be reduced from 5% to 20%, assuming that the share of electric vehicles will be 35%. In Germany, the electric vehicles are exempt from annual taxes for period of 10 years. Estimations are that the driving of electric cars represents a fifth of consumption the traditional cars (gasoline/diesel car per 100 km). In the United Kingdom, vehicles that emit less than 100g CO₂/km are exempt from the annual taxes. Germany the strongest economy in Europe, also wants to ban the sale of gasoline cars by 2030. Thus, the Netherlands want to go the same way as planning to ban the sale of gasoline engines by 2025. Unlike in most European countries, hybrid or electric cars in Serbia are a rarity. In addition to the lack of appropriate infrastructure for charging, the biggest obstacle to purchase these types of vehicles in Serbia is their price or the unwillingness of our country to subsidize the purchase of electric cars and encourages customers providing the other benefits. Croatia is far ahead of Serbia. In order to encourage citizens, the firms and private companies when purchasing the new vehicles to choose those ones that less pollute, the Croatian Ministry of Environmental and

Nature Protection and the Environmental Protection and Energy Efficiency Fund announced a public call for co-financing the purchase of electric and hybrid cars, electric scooters and motorcycles. Individuals may get an incentive for one vehicle; a prerequisite is that it must be kept in their property for at least a year, while companies can get around 91,500 Euros for several vehicles that must be kept in the property for a minimum of three years. The purchase of new vehicles, which can be purchased in any EU country, but must be registered in Croatia, is subsidized as well. The incentives for electric vehicles are up to 9,150 Euros, and for hybrid "plug-in" vehicles up to 6,550 Euro. The novelty is that as of 2015 incentives were being given to purchase the electric vehicles with built-in system for extension the movement (electric vehicle with a gasoline engine that serves solely as a power generator), and this is for models with emissions up to 50 g of CO₂/km. The following calculation demonstrates that the electric vehicles emit lower amount of CO₂ in comparison with hybrid and gasoline vehicles.

Car on motor fuel gasoline consumes 9.5 l/100 km (average for 2015 model year) times 2.31 kg CO₂ emitted per litre gasoline burned. 21.9 kg CO₂ per 100 km travelled is emitted in the atmosphere.

Electric car: 17.9 kWh/100 km (70 kWh Tesla Model S), with the charger efficiency 80% (factory of electric cars Tesla claims that some users report 95%, and some users report 80%) times 0.527 kg CO₂ per kWh (EPA average, includes line losses on the) equals 11.8 kg CO₂ per 100 km travelled.

The average American using a gasoline vehicle emits around 300 g CO₂/km, while the new hybrid, a mixture of electric

and gasoline vehicle emits 180 g CO₂/km. The law requires that the new vehicles registered in the EU by 2015 do not emit more than an average of 130 g of CO₂/km [16]. By 2021, according to the new European standard for CO₂ emission, the requirement to be achieved by the new cars is 95 grams of CO₂ per kilometre with a gradual reduction to 65-70 g/km by 2025 and 65-70 g/km by 2030[13].

Table 2 *Number of registered EV, the EV market share, CO₂ emissions, the number of public and private charging stations, the total number of EVs per million inhabitants in the world 2014-2015 [16]*

Year	2015	2014	2014	2015	2015
Country	Number of registered electric vehicles	Market share by countries	Emissions of new passenger cars g CO ₂ /km(*)	Number of private and public charging stations	Total number of electric vehicles per million inhabitants*
China	600000	1.0	-	46657 (Pu and Pr)	265
SAD	474000	0.7	225	28150 (Pu)	1340
U.K.	91000	1.0	125	8716 (Pu)	933
Norway	135000	23.3	110	6357 (Pu)	15143
Germany	75000	0.7	132	4787 (Pu)	664
Holland	113000	9.7	108	17786 (Pu)	6280
France	108000	1.2	115	10122 (Pu and Pr)	970
Slovenia	239	-	-	-	-
Croatia	87	-	-	-	-
Serbia	13	-	-	-	-

3 TENDENCIES AND TRENDS ON THE WORLD MARKET RELATED TO THE GREEN MINERAL LITHIUM

Trends on the world market show that lithium will be more profitable and that this mineral is getting epithet as pointed out by Goldman Sachs – the new gasoline or white oil. It envisages that its use in electric vehicles will grow 11 times and that is more than 300,000 tonnes by 2025. This calculation becomes obvious when the fact is taken

into account that hybrid and electric cars contain 40 to 80 kilograms of lithium [7]. This is confirmed by the price of lithium per ton which escalated in China from \$7,000 in a mid 2015 to over \$20,000 per ton of lithium in March 2016, so that the prices in the reporting period have grown more than 300% (Graph 1).

Graph 1 Change the price of lithium in China, January 2015- March 2016[15]

Demand for lithium in the world grew by 11 percent between 2010 and 2015, and export price of 99 percent pure lithium carbonate in China has more than doubled at the end of 2015. It is expected that the global demand for lithium will grow from 280,000 to 285,000 tons by 2020 (in 2015 was 163,000 tons). A half of the lithium carbonate world market is controlled by only two companies. At this

stage during 2016, the market is supplied by the Greenbushes mine in Western Australia, which is the property of Talison Lithium (51% owned by China Chengdu Tianqi, and the rest owned by giant chemical industry Albemarle based in Baton Rouge, Louisiana). Australia, Chile, and Argentina are the largest producers of lithium with 89% of production in the world (Figure 1).

Figure 1 Lithium producing countries in the world in 2015 (percentage) [20]
(Source: U.S. Geological Survey)

Table 3 *Global production, reserves and resources of lithium by country 2013-2014[22]*

Country	Production 2013	Production 2014	Reserves	Resources
SAD	870	NA	38,000	5,500,000
Argentina	2,500	2,900	850,000	6,500,000
Australia	12,700	13,000	1,500,000	1,700,000
Bolivia	-	-	-	9,000,000
Brazil	400	400	48,000	180,000
Chile	11,200	12,900	7,500,000	7,500,000
China	4,700	5,000	3,500,000	5,400,000
Portugal	570	570	60,000	-
Zimbabwe	1,000	1,000	23,000	-
Others	-	-	-	4,000,000
Total	33,940	35,770	13,519,000	39,780,000

Viewed from the standpoint that this is the mineral of the future, our stance is that the world instead of being dependent on oil could become dependent on lithium. Lithium reserves are mainly found in two countries: China and Chile. Therefore, it is important to plan in order to avoid bottlenecks and unnecessarily high prices. In general, lithium is the limited resource in the world, and production cannot be infinitely large due to the geological, economic and social constraints.

In fact, the reserves are those quantities that are usable from the viewpoint of current socio-economic conditions. To the contrary resources are more academic categories and denote a geological amount of metal available for exploitation. The concentration of metal in several countries has dropped, what could lead to more expensive and deficient acquisition of lithium in the future [8] (Table 4).

Table 4 *Worldwide lithium resources and reserves in 2014[2]*

Country	Resources	Percentage	Reserves
Argentina	6.5 mil. tons	17%	850
Australia	1.7 mil. tons	4%	1,500
Bolivia	9.0 mil. tons	23%	24%
Russia	1.0 mil. tons	3%	-
Canada	1.0 mil. tons	3%	-
Chile	7. 5 mil. tons	19%	7,500
China	5. 4 mil. tons	14%	3,500
Congo	1.0 mil. tons	2%	-
Brazil	180.000 tons	,	48
Serbia	1.0 mil. tons	3%	-
SAD	5.5 mil. tons	14%	38
Austria	130,000 tons	-	-

4 THE JADAR PROJECT - ENVIRONMENTAL AND ECONOMIC OPPORTUNITY FOR SERBIA AND MINERALS LITHIUM AND BORATES

A discovery of Jadarite has taken place relatively recently. It was discovered in 2004 by a geologist Bob Kellie in Jadarit valley near the village of Draginac in the picturesque valley on the Cer Mountain near the town of Loznica. Jadarite is an excellent source of lithium and borate. Lithium is an important component that is mostly used in hybrid and electric cars. Borat in jadarite can be used for products such as glass, ceramics, fertilizers, detergents and many other products. Serbia with the Jadarit mine covers 3% of the resources in the world, and 10% of the world demand for this resource with 80% of reserves in Europe. Researches, conducted by Rio Tinto clearly, tell us that this mine is rich in lithium and borate prompting scientists to name it Jadarit. According to an assertion, made by the company Aker Solutions, the sites at 300-600 meters depth with approximately 227 million tons of ore Jadarite could provide 1.6 million tons equivalent of lithium carbonate, and 8.1 million tons of boric acid [17]. The other studies support this endeavour and as of 2013 Jadarite mineral resources are estimated at 118 million tons at an average grade of 1.6% lithium oxide, and 18 million tons of resources borate [23]. So far, Rio Tinto has invested about 70 million dollars in the Jadar project.

Donji Jadarit (Lower Jadarit) zone has 125.3 million tons of Jadarite ore at a weighted average of lithium oxide Li_2O with concentration of 1.8%, and 16.2 million tons of borates B_2O_3 or 12.9% borate [9]. The Borate project in Serbia comes amid forecasts of increase in the global demand for these minerals on the market in value of about 4.9 billion dollars annually [3]. It is expected that the global demand for borates

B_2O_3 will increase up to 2.2 million tons (Mt) in 2018, compared to 1.5 million tons (Mt) in 2009. Using fairly conservative calculation for Jadarite ore, it represents a financial value of 80 billion dollars for Donji Jadarit zone[1].

Price of boric acid as borate product is in favour of the Jadar project and ranged from 800 to 1000 dollars per ton in 2015. China is the biggest borate consuming country with GDP which generally in this economy is slowing down, but with a robust demand for borate. Global consumption in the world is expected to remain strong, primarily in the ceramic industry, agriculture and other activities in which the borate is being used. Unlike many raw materials such as iron ore and coal, demand for borate is more correlated with middle and higher class of durable consumer goods. US are the second largest borate consuming country in the world. Global demand for borate will reach 2.2 million tons in 2018, compared to 1.5 million tons in 2009 [4]. With this lithium and borate resource potential, Serbia could be well positioned on the green minerals market. The Jadarit mine would directly employ 450 people and about 800 to 1,000 workers in the very near future that would be indirectly related to the mine. With a designed exploitation for 50 years, the Jadarit mine should ensure not only the long term economic prosperity of the region, but the whole of Serbia. Some estimation show that the Jadarit mine near Loznica would bring 30-40% of total re-venues of the municipality. If the experience of Bolivia is used, it is very interesting because this country has large lithium reserves under the Uyuni salt desert, which is at this point and tourist attraction of the country. In

addition to the ore extraction, the President Evo Morales asked investors to open a lithium battery factory, and even start producing the electric cars. We suggest

that Serbia just like Bolivia use this expensive and rare mineral and that this mineral becomes a way to initiate an investment here.

Table 5 *Jadarite resources in Serbia*[14]

	Tons (Mt)	Li ₂ O%	LCE	Compatible
Donji Jadarit	125.3	1.80%	5.58%	JORC Compliant
Gornji Jadarit	46	1.50%	1.71	NI 43-101 Compliant
Srednji Jadarit	34	1.50%	1.26	NI 43-101 Compliant
Total	80	1.50%	2.97	NI 43-101 Compliant

Figure 2 *Mineralization in Jadarite divided into upper, middle and lower layer of lithium mineral and sodium borate ($\text{Na}_2\text{B}_4\text{O}_7$), calcium borate ($\text{Ca}_2\text{B}_6\text{O}_{11}$) and sodium-calcium borate (NaCaB_5O_9)*[14] (Source: Rio Tinto Jadar factsheet, September 2011)

Typical lithium minerals have lithium content from 0.5% to 2% and in some cases of extremely high-quality content and over 3% as demonstrated by the geological properties of lithium in Jadarit shown below (Table 6). The deadline for the exploitation of this resource in the world is the longest in Australia, Canada, the United States, the Democratic Republic of Congo and Serbia

(in Jadarit). The percentage content of lithium and hence the quality of the ore in Serbia is among the highest in the world. According to some studies, better values of lithium in the world are only in Australia in its Greenbushes mine, Canada with Bernic Lake mine (2009 ceased to be exploited), Namibia and Zimbabwe, with its Bikita mine [18].

Table 6 *Geological properties of lithium mineral in Jadarit–Serbia*[8]

Name	Formula	Content(% Li)	Hardness	Density g/cm ³
Jadarite	$\text{LiNaSiB}_3\text{O}_7(\text{OH})$	3.16	4-5	2.5

5 CONCLUSION

There is a tendency for lithium in the next period to become the first mineral of green revolution that awaits us in the future. Lithium is not part of the global chain like oil, coal, iron, copper and other metals, but it is certainly on its way to become the first resource of energy supply in the world. The four main producers Chile, Argentina, USA and China are controlling 85% of world supply, and the main reserves of this mineral are located there. Therefore, the price of lithium will continue to be exerted, and it will be under continuous exertion by the major producers, after all, and due to poor utilization of capacity. The fact confirming this statement is that today many prices of goods are in the recession while only the lithium price is on the rise.

This can lead to the onset of the crisis in supply of lithium due to a bottleneck, and that is the reason why prices are high in perspective, even more than before. In addition to the above mentioned economies, Bolivia, Chile and Argentina, in the future will become the key players in lithium industry. The result of green revolution indicates a shift towards hybrid and electric cars and thus lithium batteries. As estimated all these electric cars factories will require 100,000 tons of lithium carbonate by 2021. This initiative with regard to the use of electric cars has been continuously supported by the government initiatives of the major economies of the world. All this contributed to the fact that lithium batteries denote green energy in the world today, and especially in the future. Many countries are focused at reducing carbon dioxide emissions and the use of clean energy has become a basic question of European and international environmental policy.

However, the structuring of reserves and resources in the world, carried out by four major producers, raises a question of oligopoly position of those countries, because

there is a limited number of suppliers and thus challenged projection of the electric car factory success in the world. Due to these dominant producers, our opinion is that the potential Jadarit mine in Serbia should be seeking opportunities. The final goods containing boric acid and sodium carbonate could meet demand not only in the region, but wider in Europe and the world. This is undoubtedly an opportunity for growth in exports through lithium processing and production of final goods.

As per mining and lithium minerals, the effects of ore processing are visible in three to five years, and even longer. Money turnover in the mining industry is very slow. Estimations of Rio Tinto for Jadarit mine near Loznica show that, although the lithium and boron mine fields in Serbia are profitable, it takes about six years to organize the exploitation. Hence, it raises a question whether the assessments of economic and environmental effect of this mineral in our country are cost-effective just from the viewpoint of our economy, because investments in mining are visible only in a few years.

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