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Batteries Charging the Future:

The New Cycle for Energy Storage, and the Global Arms Race for It

Techno-Sustainability Series – 2

Abstract:

Batteries represent a challenge and an opportunity for energy transition projects in Europe. While they play the central role of enablers of the sustainable transition in energy storage, problems in the supply chain of materials and components, and a strong dependency on foreign markets could put the sustainable transition at risk. While targeted investments are needed to revive the energy storage market and industries, existing technologies can be used for a made-in-Europe supply chain while also avoiding legislative bottlenecks.

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Executive Summary

The EU's plan to move towards achieving net-zero levels of emissions in the next 30 years needs bold economic and industrial policies, which were put forward in the Commission's 'Fit for 55' package (FF55). The FF55 is ambitious and necessary, but it comes with costly trade-offs and many checkpoints towards 'greening' our future. Whereas the 'green' agenda envisages only a single path, trust in the role of technology and innovation is needed for Europe to be open to new and perhaps unforeseen ways forward for economic and human development. Instead of a narrow, unbending, and dogmatic approach, it is time for us to recognise the many roads to a net-zero future.

Seeking a sustainable future without a strategy for engaging cutting-edge technologies would be a risk, both to investments and Europe's strategic autonomy. Meanwhile, EU Member States' joint effort to bring together technologies, knowledge, and resources to achieve a techno-sustainable future will contribute to a better tomorrow. It will enable us to take advantage of the fourth industrial revolution with its technological advancements and translate them into a concrete sustainability project providing technological and market-based solutions to environmental problems.

The ELF's Techno-Sustainability Series is built on the assumption that technology is our ally in tackling climatic and environmental challenges. Existing applications of AI and quantum computing, new generations of networks, and the Internet of Things (IoT) can already help in preventing energy poverty, enhancing energy efficiency in housing, and providing data and information to help achieve better living standards. Moreover, the techno-sustainability matrix will also contribute to creating new business opportunities that could boost the EU's economy. New and existing technologies are the pivotal point around which to construct the whole discussion about sustainability in Europe.

The electric revolution meant to replace fossil fuels should be strategically coordinated among Member States, both in terms of supply and value chains. This can only be achieved through a shared approach to the electric vehicle (EV) industry. A common effort is needed to make the supply chain of components a strategic priority, while encompassing new sustainable ways of production and rethinking the EV battery lifecycle. All this will have to happen through a bottom-up approach, which considers stakeholders' knowledge and priorities, and offers citizen-friendly solutions.

While battery technologies already exist for connecting the energy transition to the energy storage market, much more investment is needed in R&D in Europe. We also need a clear scheme for certification as well as targeted investments within the industry and in terms of public acceptance. This can foster a culture of sustainability: the importance of batteries to the EU's electric future is undeniable, and cutting-edge technologies must be used. However, clear policies are needed – and need to be understood and well communicated.

Recommendations

- The need for energy storage solutions and battery production is a strategic issue that European institutions should embed in their strategic planning for fully unleashing the electric revolution.
- The EU should develop close public–private partnerships in terms of promoting investments and joint ventures in mining projects to secure raw materials.
- It will be essential to foster proactive mining culture and support it through EU institutions' approvals and investments.
- Specialised training in schools and universities in this sector is essential to achieve the know-how necessary to make manufacturing plants successful.
- Investment in recycling technologies and developing the infrastructure to be able to collect, transport, and recycle are essential.
- Subsidising the sales of recycled materials to be on par or lower than virgin materials and enforcing through legislation a certain percentage of raw material to be used from recycled materials will greatly promote the recycling industry at the early stage of this revolution.

The EU has the opportunity to foster the development of a flourishing market based on a different paradigm: the one complementing environmental governance with advanced technological and market-based solutions. This will enable Europe to secure its place not only as a global frontrunner with regard to 'carbon targets' and 'emission crops' but also as a provider of best practices in terms of growth, circularity, and sustainability for our future. Climate goals should be eco-pragmatic and follow a realistic approach towards making our future more sustainable and more prosperous. Instead of a Green Utopia, our climate goals need to be based on a realistic vision for a techno-sustainable future.

Introduction

Storing electricity will be a crucial part of the European decarbonisation initiative and is an important complement to fluctuating energy sources (e.g., solar and wind), balancing the energy demand-supply chain even in a situation when no energy can be produced. Thus, batteries can play the central role of enablers of the sustainable transition in energy storage. New technologies and materials, a valuable life cycle, and manufacturing will enable large-scale deployment of devices to allow us to drive electric cars, use increasingly intelligent IoT devices, and create energy-self-sufficient houses or communities. On the other hand, this will only be possible through targeted investment in research and development while rethinking the production and recycling process, and considering a smart way of mining the necessary materials on European soil. Against the background of the sustainable transition, it is necessary to achieve the electrification of our future while also promoting the possibility of achieving energy independence by starting at the local level and exploiting the possibilities offered by energy storage systems.

The challenge of energy: storing power for our future

The invention of batteries is the result of the findings of scientific studies on electricity. Since the dawn of physical studies on the phenomenon of electricity, the idea of being able to 'trap' the power produced by various means has prompted scientists to create devices that were able to store this energy. Our relationship with electricity has its roots in Ancient Greece, and we can find traces in the script about of Thales of Miletus, who observed the electrical properties of amber. It is not a coincidence that the Greek word for amber is elektron, from which the modern term 'electricity' is derived (Meyer, 1972: 4–5). Jumping around 30 centuries into the future, the development of electrochemistry has led us to have batteries in our pockets and use them in our daily lives.

The basic idea behind a battery is to create a chemical process to release energy. Inside a battery device, this happens in a 'cell' composed of a simple electronic circuit allowing electrons to circulate from the negative toward the positive charge (anode to cathode) via an electrolyte.[1] The electrons move from anode to cathode when connected externally through a copper wire whereas the ions move through the electrolyte inside the cell – and this allows some batteries to be rechargeable. Inside the cell, the anode and cathode are separated to ensure there is no contact between them, as that would cause a short circuit.

Batteries can be defined as electrochemical devices in which an electromotive force is generated from chemical reactions. Modern chemistry and advancements in the industrial manufacture of batteries have made these devices smaller and longer-lasting. The batteries we use for energy storage are of different kinds and are built using different materials. The first distinction is between *primary* and *secondary* batteries. While the latter have the capacity of reversing the flow of energy into them once discharged, primary batteries, which consumers commonly use, can be discharged only once, and are made of materials such as zinc-carbon, zinc chloride, alkaline manganese, and lithium (Placke et al., 2017).

Despite the many types of batteries created over the centuries, *'the identification of solutions for efficient batteries is a highly difficult task [and] only very few efficient battery configurations have been successfully designed over the years'* (Ramstrom, 2019). The materials as anticipated may vary, and current

[1] Electrons are subatomic particles, found in all atoms, with a negative charge. Electrons act as the primary carriers of electricity in solids.

technologies rely on a different range of materials. For instance, the majority of cars still start their engines using lead-acid batteries, which were invented about 160 years ago by the French physician Gaston Planté (ca. 1860). Another example is alkaline batteries, whose development started more than a century ago. More recently, the creation of lithium-ion batteries can be identified as the technological advancement that has enabled the mobile revolution, allowing for greater efficiency and portability in the energy storage process.

Lithium's properties are ideally suited for use in batteries. It is the lightest metal, and its physical characteristics make it suitable also for high-voltage battery cells. Lithium is used in batteries together with other materials for the cathode (manganese, iron, cobalt, nickel) and the anode (silicon, carbon). After many years of experimentation, and the use of various materials for the electrolyte solution, the first commercial lithium battery was released in 1991 (Nishi, 2001), paving the way for the mobile revolution and the switch towards e-mobility as an alternative to vehicles running on fossil fuels (Ramstrom, 2019: 10). Lithium-ion (Li-ion) batteries represent one of the most advanced forms of battery technology, especially for smaller and lighter portable devices, as they are significantly smaller than traditional batteries. More recent developments and research projects aim to replace the liquid electrolytes with solid materials, which should offer much higher energy densities than liquid Li-ion batteries. In order to achieve this goal – much more important, as described below in terms of technological sovereignty – the new materials should have high conductivity and low resistance, while at the same time being stable and preventing lithium propagation (see Taylor & Sakamoto, 2019). Technical challenges remain in this field, mostly concerning the materials, but also regarding stability during cycling. Moreover, future technology shifts in the field of battery construction (e.g., solid-state batteries) will rely on the same lithium-based supply chain.

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Materials

As briefly described, building any kind of battery involves the use of (electro) chemistry and thus many different materials are involved. In the case of Li-ion batteries, the most common example is the batteries used in smartphones and portable devices, which use lithium cobalt oxide for the cathode,[2] and graphite for the anode. In recent decades, we have seen an increase in the number of materials used in energy storage technology. The increase in dependency on these materials has led to them being classified as critical raw materials (CRMs).

Based on the current need and availability of those materials, supply risks, and the economic implications, the EU Commission reviews a list of CRMs every three years (European Commission, 2020). Currently, the major supplier of CRMs (both for Europe and other countries) is China, both in terms of extraction and processing (European Commission, 2022). At the same time, more than 50 per cent of cobalt mined is sourced in the Democratic Republic of Congo, and lithium mainly comes from Australia, Chile, China, and Argentina (Besta, 2020). Countries that hold CRMs hold the oil of the future, in terms of the electric revolution.

This has different implications in terms of supply chains, industry, and geopolitics, considering the dependency on Asia as a problem both in terms of sovereignty and strategic autonomy. To overcome this dependency, it will be necessary for the EU and its stakeholders to rely on an internal market for raw materials. This can be achieved through the strategic and environmentally responsible actions of recycling and ethical sourcing. While the recycling option is much more needed in terms of the circularity of the battery economy, the EU only produces a small percentage of the required CRMs. Considering that the EU's lithium resources are scarce and of low quality (similar to the oil/gas situation) (Ivanics, 2021), it should build up a strategic partnership with a player that has an abundance of lithium, for instance Australia. Beyond mere mining and extraction, creating a strong partnership with lower-risk geopolitical actors will be central to the future of EU sovereignty.

> There is currently no self-sufficient supply chain in Europe that can guarantee a reliable amount of the materials needed for in-house battery production.

Cycle and (circular) economy

As mentioned above, there is currently no self-sufficient supply chain in Europe that can guarantee a reliable amount of the materials needed for in-house battery production. Moreover, the amounts of CRMs on European soil don't match the increasing need and demand for these materials. Therefore, Europe, and the manufacturers who use these materials,

[2] About half of the current supply of cobalt is incorporated into such batteries for electric vehicles and consumer electronics.

must import them from other continents. This is a problem in the light of the goal to implement the so-called electric revolution before 2050 because of the exponential increase in demand for these materials expected in the coming decades. It has been estimated, for instance, that the cobalt demand in 2030 will correspond to 280 per cent of the 2016 refinery capacity, and while the authors found that the current supply of the metal is enough to match the 2030 goals, the increase in demand, in the long run, will require the industry to invest in more efficient refining and in recycling (Fu et al., 2020).

Extracting raw materials from the soil is basically an activity of filtering and filtering again to separate refined materials from the processing slags.[3] In the context of sustainability projects in the EU, ethical sourcing can be defined as a way to guarantee that the products are made through ethical (and sustainable) methods (Lambrechts, 2021). The lithium mining industry globally meets these standards, since there is no artisanal mining for lithium. Western and especially Australian requirements are very high for mining in general, and this would be also a useful benchmark to use in the EU for new mining facilities.

In respect of raw materials, the process entangles the whole value chain, with the EU's aim being to increase resilience and (strategic) autonomy of the supply chain. First, it encompasses a series of practices for the mining cycle, while mining at EU standards, to achieve 'made-in-Europe' mining. This comes with problems both in terms of soil exploration and exploitability, and the social acceptance of the extraction and processing practices (Kotkina et al., 2018). Nonetheless, the availability of certain CRMs on European soil leaves space for a thoughtful discussion around the new techniques and standards that could be implemented to achieve an internal European supply chain in this sector (Euro Geo Surveys, 2016). Much more investment is needed in this market, which remains essential to succeed in achieving (strategic) autonomy.

> Recycling raw materials could be the key to a transition towards a sustainable electric revolution in Europe [and] could be a way out of the dependency on non-EU suppliers.

[3] Direct lithium extraction (DLE) is the predominant extraction technique to produce lithium from brines (in Chile, Bolivia, and Argentina), together with hard-rock mining and other technologies; see Warren, 2021. The extraction of cobalt is the process of separation of the material from its ores. There are several methods to do this; they all involve separating cobalt from nickel and copper. 'Cobalt extraction routes can be in the form of open-pit mining, underground mining or a combination of open-pit and underground mining depending on ore grade, size and surface type'; Farjana et al., 2019.

On the other hand, the European Commission identified 'reducing and reusing' materials as the main way to achieve strategic autonomy in the sector (European Commission, 2020). Recycling raw materials could be the key to a transition towards a sustainable electric revolution in Europe. Despite not being a diffused practice in the EU, the recovery of CRMs inside the lifecycle of those materials, the availability of technologies, and the innovative potential that the sectors present for the internal market could be a way out of the dependency on non-EU suppliers (Blengini et al., 2019). Moreover, it can be a risk-reducing factor and help to diversify the supply chain (Blengini et al., 2017: 21–24). For instance, many valuable materials can be recovered by dismantling Li-ion batteries through the disassembling phase and mechanical and chemical processes.

A major point in the carbon-free transition concerns the life cycle of batteries. The concept of battery second life goes hand in hand with the sustainability of the whole battery life cycle, with direct implications for reducing greenhouse gas emissions (especially during manufacturing). Moreover, together with the recycling of materials and components, batteries can be reused once their capacity is not sufficient to ensure high performance, for instance, in an electric vehicle (EV). These aged batteries can be used in an Energy Storage System (EES), working at low discharge rates and ensuring the continuity of a broader electrical grid or system, for instance, in a self-sustaining home environment powered by solar energy.

However, some challenges exist for recycling. Since the EV sector is still in the nascent stage, the availability of Li-ion batteries for recycling is considered to be a long way off – potentially post-2040 – after these batteries are depleted after their second use in a significant amount to provide, for instance, energy storage. By that time, the recycling technologies will have to be efficient enough to guarantee that recycled materials can replace virgin raw materials. This also requires recycling procedures to ensure low greenhouse gas emissions. Finally, since Li-ion battery technology is still developing, it is difficult to know which type of battery will be the standard and adapt recycling technologies accordingly.

EU context and strategy on batteries

While exploiting the potential of the means that allowed the mobile revolution, with sustainability as a core benchmark, the European institutions are committed not only to considering all the possible alternatives for a more sustainable lifecycle for batteries, but also to strengthening the internal regulatory framework so that it can enhance the opportunities offered by the innovative sector.

Acknowledging the role battery technology will play in the transition to a sustainable, circular economy, at the end of 2020, the EU Commission proposed a new sustainable batteries regulation that seeks to make batteries safer, bolster protection of the environment, and promote the recycling and reuse of batteries (European Council, 2019). The new regulation will harmonise requirements for batteries and ensure that all batteries circulating in the EU market are sustainable and safe. Pursuant to the regulation, batteries are to be long-lasting, safe, produced with the lowest possible environmental impact, and repurposed or recycled at the end of their lifecycles. This new initiative is inherently linked and is designed to advance the larger goal of increasing sustainability and achieving climate neutrality by using sustainable, clean technologies and processes.[4]

This regulatory proposal grounds itself in the Circular Action Plan (European Commission, 2020a), released in March 2020, which is a crucial feature of the European Green Deal and the Commission's plan to boost the economy with higher levels of sustainability (European Commission, 2019). The action plan includes measures to be implemented across the entirety of a product's life cycle, from design and manufacturing to the recycling phase. The sustainable batteries regulation is welcomed as a tool to enhance the sustainability of the emerging battery value chain and harness the circular potential of batteries available across the EU market.

Another tool aiming at increasing reliance on sustainable batteries is the European Battery Alliance (EBA, n.d.), launched in 2017. It brings together EU Member States, industry, the scientific community, and other stakeholders in the battery value chain. The alliance now numbers 440 members and strives to facilitate collaboration between stakeholders by creating a forum where strategic plans and strategic actions contributing to the development and sustainable use of batteries can be formulated and enacted. Like the EBA, the European Raw Materials Alliance is a flagship initiative addressing challenges regarding raw materials and determining the role of raw and advanced materials in the transition to a sustainable and digital economy (ERMA, n.d). In addition, it aims to bolster the resilience of the supply chains and attract investments in the industry and harvest young talent.

The (strategic) problems of dependency

As anticipated, one of the main problems concerning the supply of batteries remains that the cells used for manufacturing electronics in Europe are provided by other markets (mainly China, Japan, or South Korea). China won the race to build batteries long before the electric revolution in Europe, investing extensively in strategic mining sites and R&D into this technology (Zhang et al., 2020). Furthermore, China's dominance of the raw materials supply chain doesn't come entirely from extraction, but from its imports from Australia and South America, coupled with the domestic implementation of the chemical stages. China developed technologies in the chemical processing of lithium minerals in recent decades, recognising the critical importance of this sector, which resulted in an important comparative advantage. The Chinese chemical industry alone supplies more than 60 per cent of the chemical procedures and refinement required

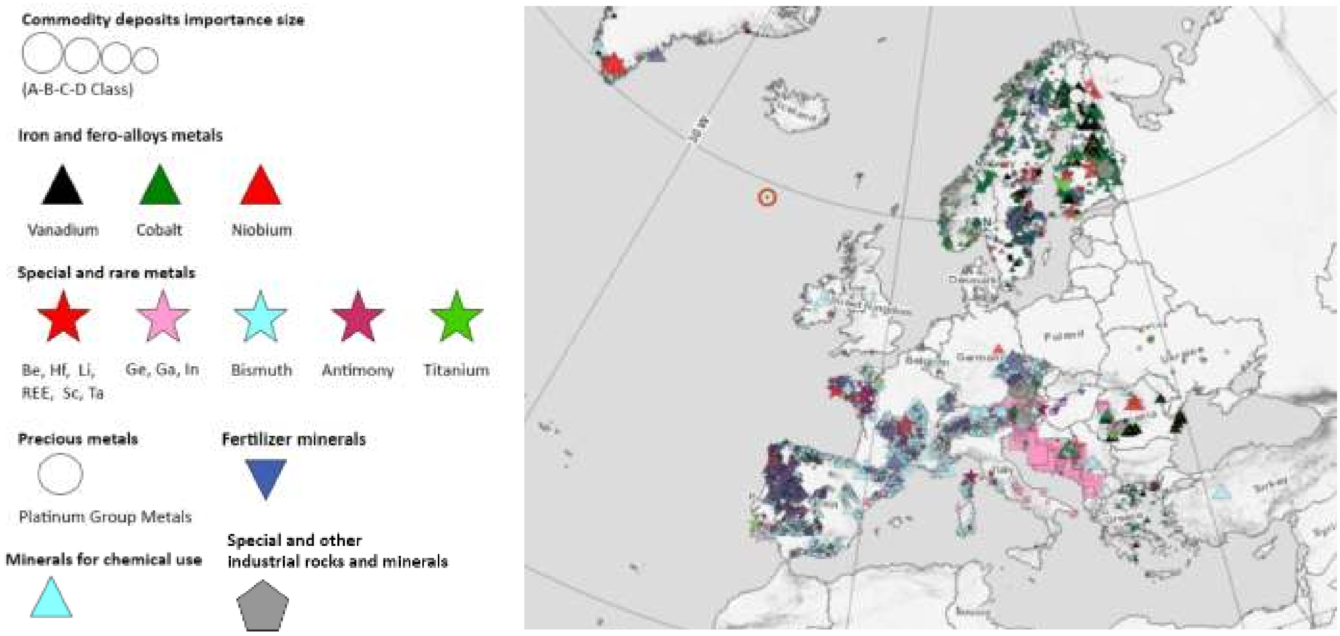
[4] Prior to the new, proposed regulation, the 2006 Directive on Batteries (later amended, most recently in 2020) governed the use of batteries. With the entry into force of the new regulation, the 2006 directive will be repealed.

to obtain the specific purity needed for battery materials (Moores, 2021). This, together with the predominance of Chinese companies in cell manufacturing, represents a competitive advantage with direct implications for the European market, also in terms of direct foreign investment.[5]

In respect of the suppliers' value chain, the battery industry in China remains highly automated and based on personnel trained with precise technical skills, in partnership with universities. Finally, it is worth mentioning that, in the past, most patents in this technology were held by US, EU, Japanese and South Korean companies in the past, while nowadays they have been sold or licensed to Chinese companies. However, the production areas of battery components are covered by corporate secrecy and are often off-limits, due to a very competitive market. Intellectual property thus contributes to making these companies maintain a leading position in Asia. Mining companies and suppliers are constantly evaluated by European customers, demanding certification and undergoing due diligence (DD) procedures. Original equipment manufacturers from Europe that set up joint ventures in China ask suppliers to undergo strict DD procedures. However, the risk of violation cannot be excluded entirely.

Thus, to ensure a meaningful, strategic approach to the electrification of Europe, while ensuring standards in accordance with EU values (both in terms of extraction and pollution, and concerning human rights) (Amnesty International, 2020), it is of utmost importance to act cohesively at the EU 27 level to foster the (internal) energy market.

Figure 1: Map of CRMs in Europe. Source: EuroGeoSurveys.



[5] The first large-scale example of investment comes from Italy, where the Chinese company First Automobile Works (FAW), jointly owned by the Chinese government, invested 1 billion€, together with Silk-EV, in the so-called Motor Valley (next door to Ferrari, Maserati, and Lamborghini), to build electric supercars. Silk-FAW represents the first foreign direct investment by China in the context of mobility electrification, with expected large-scale design, manufacturing, and production on the continent. See Forbes.it, 2021.

Conclusions

Strategic policies to promote energy storage technologies are needed 'yesterday'. While the European institutions have made efforts to achieve sound legislation for a sustainable energy transition, bolstering a common European strategy for CRMs and cell supply chain is required urgently. The recent shortage of CRMs experienced during the COVID-19 pandemic might have rung alarm bells at institutions (Ivanics, 2021), but the timeframe of achievements proposed in the European Green Deal for 2030 seems to fall behind the real opportunities for the internal market to quickly adapt and build new segments of the industry for EES and battery supply.

> While the technologies already exist for connecting the energy transition to the energy storage market, much more investment is needed in R&D in Europe, together with a clear scheme for certification, and targeted investment to foster the culture of sustainability.

While the technologies already exist for connecting the energy transition to the energy storage market, much more investment is needed in R&D in Europe, together with a clear scheme for certification, and targeted investment – within the industry and in terms of public acceptance – to foster the culture of sustainability. The importance of batteries to EU citizens' electric future is undeniable and cutting-edge technologies must be used, but clear policies are needed, and have to be understood.

Recommendations

1. Resources: the EU could develop close public–private partnerships with Western Australia and South America in terms of promoting investments and joint ventures in mining projects to secure raw materials.
2. Mining in the EU: developing a proactive mining culture and supporting it through EU institutions' approvals and investments is critical
3. Subsidies: the EU's subsidies for EVs and reduction in emissions are pulling the development of the upstream supply chain. Supporting the manufacturing of cells, cathodes, anodes, and other battery materials through investment is important.

4. Technical skills: having specialised training in schools and universities in this sector is essential for making these manufacturing plants successful. The local skilled workforce is crucial, as it also has an important role in empowering local and energy communities.
5. Recycling technology: investments in recycling technologies and developing the infrastructure to be able to collect, transport, and recycle are essential. Research and development should follow the same logic of sustainability with regard to the emissions and footprint of the recycling facilities.
6. Recycling policy: subsidising the sales of recycled materials to be on par or lower than virgin materials and enforcing through legislation a certain percentage of raw material to be made up of recycled materials will greatly promote the recycling industry at the early stages of this revolution. ■

Author bio

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The European Liberal Forum (ELF) is the official political foundation of the European Liberal Party, the ALDE Party. Together with 47 member organisations, we work all over Europe to bring new ideas into the political debate, to provide a platform for discussion, and to empower citizens to make their voices heard. Our work is guided by liberal ideals and a belief in the principle of freedom. We stand for a future-oriented Europe that offers opportunities for every citizen. ELF is engaged on all political levels, from the local to the European. We bring together a diverse network of national foundations, think tanks and other experts. In this role, our forum serves as a space for an open and informed exchange of views between a wide range of different EU stakeholders.

References

Amelin, I.I. (2015). *'Creating Superconductors with High Critical Temperature Using Copper Fluoride'*. Russian Journal of Physical Chemistry, 89, 1704–1706. https://doi.org/10.1134/S0036024415090022.

Amnesty International (2020), *'South Africa: Mining Gathering Must Confront Human Rights Violations'*, 3 February, https://www.amnesty.org/en/latest/news/2020/02/south-africa-mining-gathering-must-confront-human-rights-violations.

Besta, S. (2020). *'Profiling the Top Six Lithium-Producing Countries in the World'*, NS Energy Business.

Blengini, G.A., Blagoeva, D., Dewulf, J., et al. (2017), *'Assessment of the Methodology for Establishing the EU List of Critical Raw Materials'*, Joint Research Centre, https://publications.jrc.ec.europa.eu/repository/bitstream/JRC106997/kjna28654enn.pdf.

Blengini, G.A., Mathieux, F., Mancini, L., et al. (2019), *'Recovery of Critical and Other Raw Materials from Mining Waste and Landfills'*, Joint Research Centre (EUR 29844 EN). https://doi.org/10.2760/600775.

EBA (n.d.), *'About European Battery Alliance'*, https://www.eba250.com/about-eba250/?cn-reloaded=1.

ERMA (n.d.), *'About European New Materials Alliance'*, https://erma.eu/about-us.

Euro Geo Surveys (2016). *'Critical Raw Material Deposits of Europe'*, ProMine Mineral Deposit Database.

European Commission (2019), Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions: The European Green Deal, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2019%3A640%3AFIN.

European Commission (2020). *'Critical Raw Materials Resilience: Charting a Path Towards Greater Security and Sustainability'*, 3 September, https://ec.europa.eu/docsroom/documents/42849.

European Commission (2020a), *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A New Circular Economy Action Plan for a Cleaner and More Competitive Europe*, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2020%3A98%3AFIN.

European Commission (2022), *Raw Material Information System*, EU Science Hub, https://rmis.jrc.ec.europa.eu/?page=why-crms-have-a-supply-risk-8e8af9

European Council (2019), *Proposal for a Regulation of the European Parliament and of the Council Concerning Batteries and Waste Batteries, Repealing Directive 2006/66/EC and Amending Regulation (EU) No 2019/1020*, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020PC0798.

Farjana, S.H., Huda, N., & Parvez Mahmud, M.A. (2019). *'Life Cycle Assessment of Cobalt Extraction Process'*. Journal of Sustainable Mining, 18(3), 150–161. https://doi.org/10.1016/j.jsm.2019.03.002.

Forbes.it (2020), *'Il colosso cinese dell'auto Faw investirà oltre un miliardo di euro in Italia'*, 14 May. *https://forbes.it/2020/05/14/auto-elettriche-faw-investe-oltre-un-miliardo-di-euro-in-italia*.

Fu, X., Beatty, D.N., Gaustad, G.G. et. al (2020). *'Perspectives on Cobalt Supply Through 2030 in the Face of Changing Demand'*. Environmental Science & Technology, 54(5), 2985–2993, *https://doi.org/10.1021/acs.est.9b04975*.

Ivanics, B. (2021).*'Towards a Sustainable Economy with (Critical) Raw Materials'*. In G.M. Bovenzi and F. Sampalmieri (eds.), Environmentalism + Capitalism = Happy Growth, pp. 38–67. Brussels: European Liberal Forum.

Kotkina, I., Petrov, L., & Woulé Ebongué, V. (2018), *'Social Acceptance in the European Raw Materials Sector'*, Report on workshop held in Brussels on 5 June, European Commission, Executive Agency for Small and Medium-sized Enterprises. *https://op.europa.eu/en/publication-detail/-/publication/5cb05cd5-3011-11e9-8d04-01aa75ed71a1*.

Lambrechts, W. (2021). *'Ethical and Sustainable Sourcing: Toward Strategic and Holistic Sustainable Supply Chain Management'*. In W.L. Filho et al. (eds.), Decent Work and Economic Growth, 402–414. Cham: Springer.

Meyer H.W. (1972). A History of Electricity and Magnetism. Cambridge, MA: MIT Press.

Moores, S. (2021), *'The Global Battery Arms Race: Lithium-Ion Battery Gigafactories and Their Supply Chain', The Oxford Institute for Energy Studies*, February. *https://www.oxfordenergy.org/wpcms/wp-content/uploads/2021/02/THE-GLOBAL-BATTERY-ARMS-RACE-LITHIUM-ION-BATTERY-GIGAFACTORIES-AND-THEIR-SUPPLY-CHAIN.pdf*.

Nishi, Y. (2001). *'The Development of Lithium Ion Secondary Batteries'*. The Chemical Record, 1(5), 406– 413. *https://doi.org/10.1002/tcr.1024*.

Placke, T., Klopesch, R., Duhnen, S., & Winter, M. (2017). *'Lithium Ion, Lithium Metal and Alternative Rechargeable Battery Technologies: The Odyssey for High Energy Density'*. Journal of Solid State of Electrochemistry, 21, 1939-1964. *https://doi.org/10.1007/s10008-017-3610-7*.

Ramstrom, O. (2019). *'Scientific Background on the Nobel Prize in Chemistry 2019: Lithium-Ion Batteries'*, The Royal Swedish Academy of Science, *https://www.nobelprize.org/uploads/2019/10/advanced-chemistryprize2019-2.pdf*.

Taylor, N.J., & Sakamoto, J. (2019). *'Solid-State Batteries: Unlocking Lithium's Potential with Ceramic Solid Electrolytes'*. American Ceramic Society Bulletin, 98(7): 26–31.

Warren, I. (2021). *'Techno-Economic Analysis of Lithium Extraction from Geothermal Brines'*, National Renewable Energy Laboratory. *https://doi.org/10.2172/1782801*.

Zhang, L., Liu, Y., & Pang, B. (2020) *'China's Development on New Energy Vehicle Battery Industry: Based on Market and Bibliometrics'*, IOP Conference Series Earth and Environmental Science. *https://doi.org/10.1088/1755-1315/581/1/012003.*

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