Lithium: towards a necessary sufficiency

Briefing note- February 2023

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Summary

Demand for lithium, and therefore its mining, will drastically increase during the next few years, due mostly to the rise of electric vehicles. Today, about 60% of the lithium mined in the world is used in electric vehicles, and this share is set to increase further. Some projections estimate that by 2040, the annual consumption of lithium for electric vehicles alone will be 8 times the current global mining production.

This demand explosion raises numerous issues: the ability to extract the required quantities, the potential new forms of European dependency on other countries, the industrial feasibility of such exploitation, and the major social, environmental, and health-related impacts that it generates.

In this note, the négaWatt Association analyses current and potential lithium extraction, its impacts, and possible alternatives. It also discusses the role of this metal in the négaWatt energy transition scenario for France, as well as the recent French mining project in the Allier region.

Key points:

- Lithium is mainly mined in Australia (52% of global production in 2019[1]) and in the Chilean and Argentinean salt flats (22% and 7%). In 2019, refining activities were mainly located in China (around 60%[2]), with Chile remaining an important actor (around 30%).
- Global reserves are currently estimated at 22 million tons[1].
- The extraction process causes social and environmental impacts, especially in the Latin American salt flats.
- In 2022, 74% of the lithium consumed worldwide was used in Li-ion batteries[1].
- The use of lithium within batteries is increasing rapidly due to the growing production of portable electronic devices and, more importantly, to electric motorization, which is set to develop even more rapidly in the years to come.
- Recycling is necessary, but not sufficient to ensure this important growth.
- A scenario of total electrification of French road transportation is not sustainable without sufficiency measures to contain the increase in demand! The main measures proposed are diminishing the distances travelled, modal shift, developing carpooling, limiting the range of vehicles, and reducing the size and weight of vehicles.
- It will also be necessary to develop other motorizations to limit our material footprint, such as bioNGV for heavy goods vehicles.

Technical clarification

The quantities of lithium mentioned in this note refers to lithium metal, unless otherwise stated.[3]

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[1] Mineral Commodity Summaries 2022 (p. 206). (2022). USGS.

[2] The Role of Critical Minerals in Clean Energy Transitions (World Energy Outlook Special Report). (2022). IEA. See p.13.

[3] See the annex at the end of this note on the conversion of lithium quantities (Li metal, lithium hydroxide, etc).

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Context

Alike oil at the beginning of the 20th century, and like uranium in the 1970s, lithium is becoming the "white gold" and now makes the news.

This is partly linked to the rise of the electric vehicle. Indeed, in 2022, 74% of the lithium consumed worldwide was used in Li-ion batteries, 14% in ceramics and glass, 3% in lubricating greases, 2% as fluxes for continuous casting moulds, 2% in polymer production, 1% in air treatment, and the remaining 4% in various other uses[1].

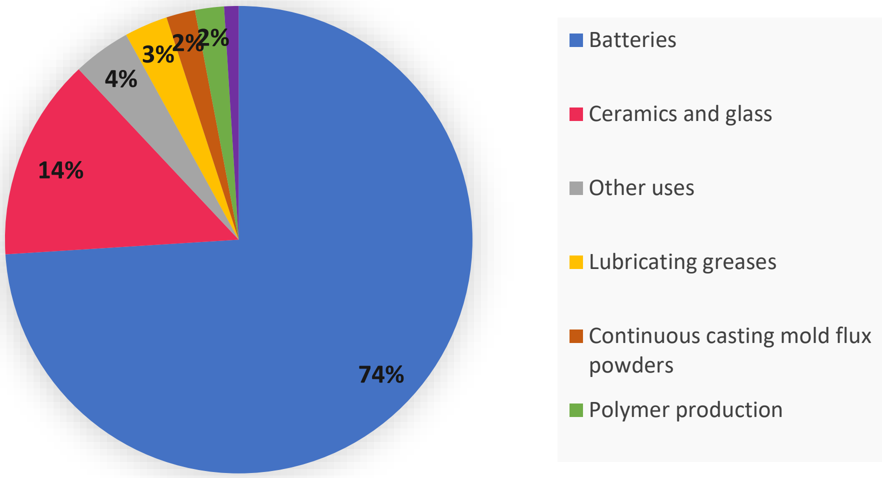

Figure 1: World lithium uses in 2022, from USGS (2022), Mineral Yearbook

Li-ion batteries (LIBs) themselves are used for about 75% of electric vehicles[4] . The increase in the share of LIB use in electric vehicles is striking in recent years, as it was still at 25% in 2018[5], where electronic use was dominant. **About 60% of the lithium produced worldwide is therefore now used in electric vehicles**.

However, the use of lithium in LIBs is increasing rapidly due to the growing production of portable electronic devices and, more importantly, to the use of battery electric vehicles (BEV), which is set to develop even more rapidly in the years to come.

According to many ecological transition scenarios, the switch from combustion engines to electric vehicles – as the European Parliament and Council have decided to end the sale of combustion engines in 2035[6] - will result in a dramatic increase in lithium consumption. In 2017, in order to develop electric mobility with the aim of staying below the global warming threshold of 2°C, the World Bank forecast that lithium consumption would rise to 20 million tons[7] worldwide between 2013 and 2050. This represents an average annual consumption of more than 500,000 tons, which corresponds to five times more than today. The International Energy Agency[8] estimates that, in a sustainable development trajectory, annual lithium consumption could

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[4] It should be noted that precise consumption data is difficult to access. Three sources have been cross-checked here:

- *Battery 2030: Resilient, sustainable, and circular* (2023). McKinsey & Company.
- Lindagato, P., Li, Y., Macháček, J., Yang, G., Mungwarakarama, I., Ndahimana, A., & Ntwali, H. P. K. (2023). Lithium Metal: The Key to Green Transportation. *Applied Sciences*, *13*(1), Art. 1.
- *Final compromise text of the trilogue agreement on batteries*. (2023). European trilogue. https://data.consilium.europa.eu/doc/document/ST-5469-2023-INIT/en/pdf

[5] IEA figure in Hache, E., Seck, G. S., & Simoen, M. (2018). What is the level of criticality of lithium for electrification of the global automobile fleet? - Panorama 2018.

[6] *EU deal to end sale of new CO2 emitting cars by 2035*. (2022, October 28). European Commission - European Commission. https://ec.europa.eu/commission/presscorner/detail/en/ip_22_6462

[7] The Growing Role of Minerals and Metals for a Low Carbon Future. (2017). World Bank.. See p.22; Figure 2.11.

[8] The Role of Critical Minerals in Clean Energy Transitions (World Energy Outlook Special Report). (2022). IEA. See p.97.

reach 800,000 tons in 2040 for electric vehicles, i.e., 8 times more than the current world production. **Such a consumption of lithium would be considerable!**

This dramatic increase in demand necessarily raises the question of its industrial feasibility, with the fear that world production capacity will not be able to keep up.

There is also a geopolitical risk linked to the concentration of several stages of production in a few countries and the resulting lack of resilience of value chains, as well as Europe's high dependence on producing countries.

Indeed, lithium is a metal that is mainly extracted in Australia (52% of world production in 2019[9]) and in the Chilean and Argentinean salt flats (22% and 7%). In 2019, refining was even more concentrated and mainly located in China (around 60%), with Chile remaining a major actor (around 30%).

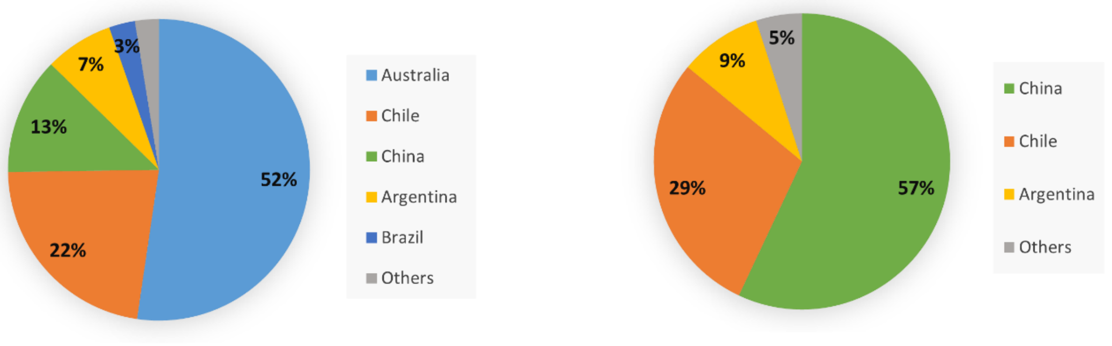

Figure 2: Main lithium producing countries

Left: Lithium mining producers in 2019, from USGS (2022), Mineral Yearbook. US production is excluded from the calculation by the USGS.

Right: Lithium refiners in 2019, according to the IEA, 2022[10]

This situation raises concerns for both European institutions and the Member States, especially now since the competition to secure supply should cause tensions between the main consumers, namely the automotive (or defense) industries.

In France, media coverage regarding the topic of lithium extraction followed the announcement in October 2022 of a large-scale lithium mining project in the Allier region by the operator Imerys[11] . This announcement fostered the debate around lithium, particularly on its mining and processing.

Finally, the forecast for a dramatic increase in global demand raises questions about its health-related, social and environmental consequences.

[9] Mineral Commodity Summaries 2022. (2022). USGS.

[10] The Role of Critical Minerals in Clean Energy Transitions (World Energy Outlook Special Report, p. 287). (2022). IEA. See p.13.

[11] Imerys (2022, October 24). Imerys aims to become a major lithium player in Europe. Press release. https://www.imerys.com/public/2022-10/imerys-communique-imerys-ambitionne-de-devenir-un-acteur-majeur-du-lithium-en-europe-24-octobre-2022_0.pdf

Impacts, recycling, and lithium reserves

Impacts of expanding mining and lithium exploitation

The increase in production and consumption of mineral resources goes beyond the case of lithium, as metal consumption has been increasing exponentially for over 100 years[12] .This situation leads to repercussions that are now reaching unsustainable levels. The UN International Resource Panel[13] and the OECD[14] warn about the increasing harmful consequences of mining, among which contribution to climate change and the impact of particulate matter on health. They also point out increasing toxicity or habitat destruction.

Researchers have also shown that past, present and future mining (assuming that all projects currently prepared were to be implemented) would cumulatively influence approximately 6.7 million km² of the Earth's surface, or about 5% of the global land area. Of this, 8% is protected area, 5% is key biodiversity areas and 16% is remaining wilderness areas. Researchers warn that without strategic planning, these new threats to biodiversity could become major[15] .

In the case of lithium, we must mention the impacts of this exploitation in Chile, which, as we have seen, represents a quarter of world production. Numerous studies[16] on lithium mining in Chile show that mining activity has caused a decrease in groundwater levels in an already very arid region, the Atacama Desert. This has led to water stress for local people, a decline in vegetation and has partially dried out the *Los Flamencos* nature reserve with an impact on biodiversity. The two lithium mining companies in the Atacama area, as well as two nearby copper mining companies, account for an extraction volume of 4,230 litres of fresh water per second. By comparison, the volume extracted to treat and distribute water to all the inhabitants of Paris is on average 5,590 litres per second[17] . At the national level, **in 2016, the Chilean authorities considered that 70% of the country's water was used for mining operations** and 17% for the agricultural sector, leaving only 13% for human consumption, which is a sobering thought given that droughts will become more frequent and severe in the coming years.

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[12] Vidal, O., Rostom, F., François, C., & Giraud, G. (2017). Global Trends in Metal Consumption and Supply: The Raw Material-Energy Nexus. Elements, 13(5), 319-324. https://doi.org/10.2138/gselements.13.5.319

[13] Global Resources Outlook 2019: Natural Resources for the Future We Want (Report of the International Resource Panel. United Nations Environment Programme. Nairobi, Kenya). (2019). IRP. https://doi.org/10.18356/689a1a17-en

[14] OECD. (2019). Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences. OECD. https://doi.org/10.1787/9789264307452-en

[15] Sonter, L. J., Dade, M. C., Watson, J. E. M., & Valenta, R. K. (2020). Renewable energy production will exacerbate mining threats to biodiversity. Nature Communications, 11(1), 4174. In this study, a cumulative footprint over time for 40 different substances is used, with an attempt to consider the mining land footprint in the broadest sense, i.e. with its potential impact on biodiversity and not just the mine's surface. We have used the study's conservative assumption of a 10 km radius of impact around the mine, i.e. an area of 314 km² per mine site (minus the overlap between sites).

[16] de Haan, E., & González, A. (2020). The battery paradox. SOMO.

Liu, W., & Agusdinata, D. B. (2021). Dynamics of local impacts in low-carbon transition: agent-based modeling of lithium mining-community-aquifer interactions in Salar de Atacama, Chile. The Extractive Industries and Society, Volume 8 (Issue 3).

Liu, W., Agusdinata, D. B., & Myint, S. W. (2019). Spatiotemporal patterns of lithium mining and environmental degradation in the Atacama Salt Flat, Chile. International Journal of Applied Earth Observation and Geoinformation.

Romero, A., Aylwin, & Didier. (2019). Globalización de las empresas de energía renovable: Extracción de litio y derechos de los pueblos indígenas en Argentina, Bolivia y Chile ("Triángulo del Litio") (p. 59). OBSERVATORIO CIUDADANO.

[17] According to https://www.eaudeparis.fr/nos-missions, which reports 483,000 m³ of water withdrawn, transported, treated and distributed each day, i.e. 5,590 l/s.

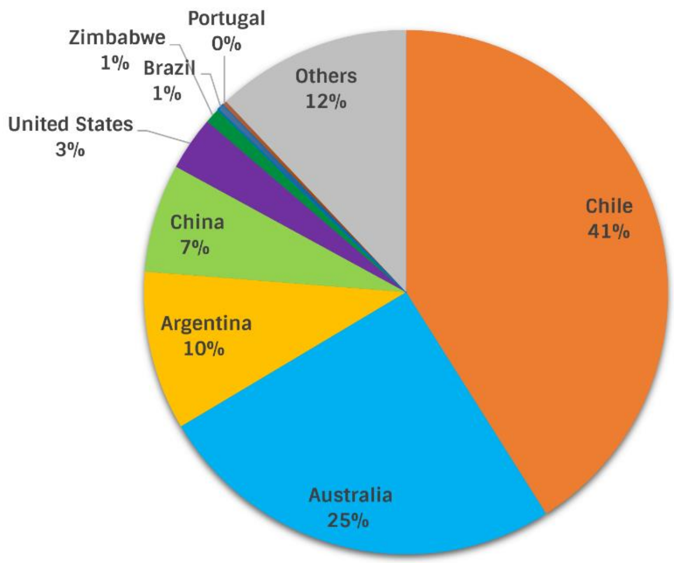

Figure 3: Major proven lithium reserves in 2021, from USGS (2022), Mineral Yearbook.
The total corresponds to about 22 million tonnes of lithium. Bolivia is counted under "Others".

The majority of the world's proven lithium reserves are located in the "lithium triangle", i.e. in the salt flats of Chile, Argentina and Bolivia. Reserves in this region are estimated to be around 14 million tons of lithium[18] , or around 60% of the world's reserves. However, the reserves in Bolivia and Argentina are located in arid salt flat ecosystems, like in Chile. The increasing impacts in the Atacama salt flat can therefore be seen as a good indication of the potential impacts of large-scale mining in Argentina and Bolivia.

In green growth trajectories without sufficiency assumptions, the exploitation of the entire salt flats will unfortunately be unavoidable to meet global needs since, as discussed previously, this consumption would be around 20 million tons of lithium by 2050 according to the World Bank[19] , which corresponds to the quasi totality of the world's current proven reserves.

Recycling and its limits

Recycling of lithium is still very limited today: only 5 to 7% of LIBs are recycled worldwide[20] and most of the time the lithium is not recycled because the recycling route used is a pyrometallurgical process aiming mainly at recycling the nickel, cobalt, and copper, and not the lithium which is 'recovered', meaning it ends up in slag (road sub-layer, concrete manufacture, etc.). The main obstacle is economical: the batteries would have to be directed towards ways of recycling the lithium, which has not been profitable until now due to the low price of lithium.

There are about fifty companies worldwide that process end-of-life LIBs. The recovery of lithium from end-of-life LIBs is mainly carried out in China, which accounts for 50% of the recycling of end-of-life batteries and

[18] Based on USGS figures for 2022 corresponding to proven reserves for Chile and Argentina and assuming that proven reserves correspond to 40% of base reserves for Bolivia according to: Aguirre B., F. (2022). The lithium triangle - the importance of Bolivia. Journal of Energy & Natural Resources Law, 40(2), 183-202. https://doi.org/10.1080/02646811.2021.1930708

[19] The Growing Role of Minerals and Metals for a Low Carbon Future. (2017). World Bank. http://documents.banquemondiale.org/curated/fr/207371500386458722/pdf/117581-WP-P159838-PUBLIC-ClimateSmartMiningJuly.pdf. See p.22; Figure 2.11. The modelling is done between 2013 and 2050, however the actual share consumed between 2013 and 2022 is very small.

[20] Pinegar, H., & Smith, Y. R. (2019). Recycling of End-of-Life Lithium Ion Batteries, Part I: Commercial Processes. Journal of Sustainable Metallurgy. https://doi.org/10.1007/s40831-019-00235-9. See p.6.

production scraps[21] , followed by South Korea, then the European Union, Japan, Canada and the United States[22]. The concentration of recycling in China can be explained by the presence of the battery manufacturing stages, allowing for a high degree of synergy between actors. Indeed, the majority of recycling is done by hydrometallurgy[23] either by the battery manufacturers themselves or by companies specializing in metallurgy. Most of the players processing end-of-life LIBs by hydrometallurgy can alternatively use products from the pre-treatment of end-of-life LIBs (blackmass), manufacturing scraps, or even concentrate from mines. The presence of numerous battery factories for electric vehicles, which themselves generate manufacturing scraps, enables recyclers to have materials to recycle in addition to end-of-life batteries. These different flows make it possible to partially overcome the obstacles to lithium recycling (variable composition of the material flow, not enough material stock, etc.).

[21] Delacroix, G. (2023, January 15). Batteries are entering their golden age, driven by the advent of "all-electricity". Le Monde.fr.

[22] Neumann, J., Petranikova, M., Meeus, M., Gamarra, J. D., Younesi, R., Winter, M., & Nowak, S. (2022). Recycling of Lithium-Ion Batteries-Current State of the Art, Circular Economy, and Next Generation Recycling. Advanced Energy Materials, 12(17), 2102917.

[23] Almost all companies use hydrometallurgical approaches in China. The main reason is the possibility to recover larger quantities of battery components and to reach very high purities. In the EU, the most common recovery methods are pyrometallurgy, hydrometallurgy and combinations of both. Neumann, J., Petranikova, M., Meeus, M., Gamarra, J. D., Younesi, R., Winter, M., & Nowak, S. (2022). Recycling of Lithium-Ion Batteries-Current State of the Art, Circular Economy, and Next Generation Recycling. Advanced Energy Materials, 12(17), 2102917.

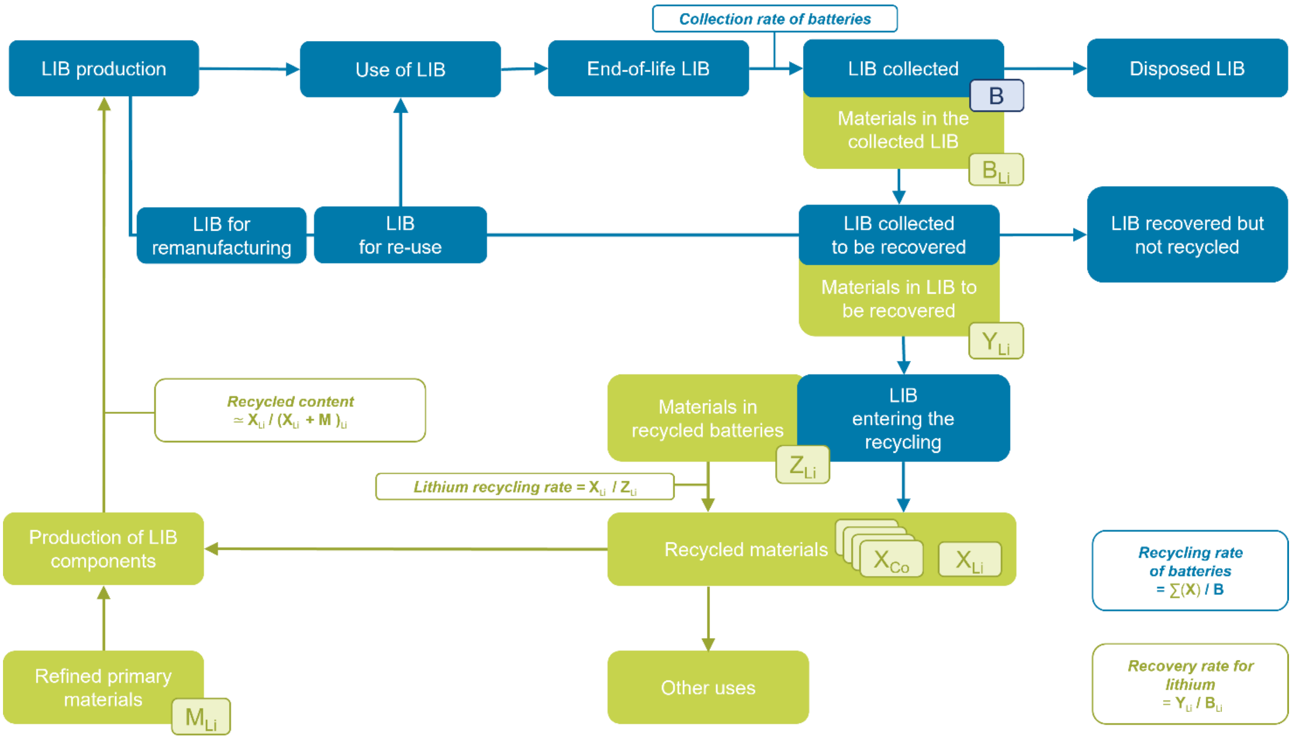

Figure 4: Diagram of the collection, recycling of LIBs, as well as the recovery rate and recycled lithium content

Legend:

1) Variables:

All variables are mass quantities.

B: collected batteries

B_{Li}: lithium contained in the collected batteries

Y_{Li}: lithium contained in batteries to be recovered (recycled lithium, contained in re-used batteries or in any type of recovery)

X_{Li}: lithium obtained (ouput of the recycling process)

X_{Co}: cobalt obtained (ouput of the recycling process)

∑(X): sum of all outputs i.e., materials obtained from recycling (Al, Cu, Fe, Li, Mn, Co, Ni, graphite, plastics)

Z_{Li}: lithium present in the batteries to be recycled (input of the recycling process)

M_{Li}: lithium from mining

2) The different rates related to recycling:

The collection rate of batteries is the ratio of the mass of waste collected from identified producers to the total mass of waste generated by these same producers.

The recycling rate of batteries is the ratio of the mass of the different products recycled at the end of the recycling process to the total mass of batteries weighed at the entrance of the treatment facility. It thus measures our ability to transform waste into secondary raw materials.

The recycling rate of a substance (not defined by trilogue agreement) is the yield of the recycling process for a specific substance.

The recovery rate is the ratio of the mass of a recovered substance[24] to its collected mass.

The recycled lithium content of a LIB is the percentage by mass of recycled lithium in the battery relative to the total mass of lithium.

[24] "Any operation whose main result is that waste is used for a useful purpose by replacing other materials that would have been used for a particular purpose, or that waste is prepared for use for that purpose, in the plant or in the economy as a whole. (Directive 2008/98/EC, Article 3, p. 8). This means virtually any use that avoids disposal. For lithium, for example, even pyrometallurgically processed lithium that is not strictly speaking recycled, that ends up in slag, recovered in road sub-base or in the manufacture of concrete is counted as "recovered". **The precise method of calculating the recovery rate remains to be defined by the Commission** following the publication of the final European compromise text of the trialogue agreement on batteries (2023).

With the increase of lithium's price, we can anticipate that in the future, lithium recycling will become more important in Europe, as is already demonstrated by the many industrial initiatives that are being launched**.**

However, certain obstacles to recycling remain: the gradual decline in cobalt content, which has reduced the interest of recyclers in material flows from pyrometallurgy (blackmass), but also the highly qualified labour required to dismantle electric vehicle batteries, the lack of standardization of batteries, and finally the lack of of refiners who are going to set up in Europe for recycling, which is less profitable than other raw materials such as salts extracted from brines in Argentina and Chile.

It therefore seems **necessary to increase the incentives of the French and European public authorities to reinforce the implementation of this recycling.** Indeed, legislation is currently being validated to develop requirements for battery recycling at the European level[25] .

Regarding the requirements for the **collection** phase of **end-of-life batteries** (see Table 1), it is regrettable that **these do not concern electric vehicles**, which are expected to become the main consumer of LIBs in the coming years.

Creating specific recycling targets for lithium (and more broadly, for each substance) **is needed**. For example, the négaWatt scenario **targets a lithium recycling rate of 80% in 2030** (see Figure 4 and Table 1). **In contrast, today the recycling rate requirements** (see Figure 4) **are set for the sum of recycled materials from batteries and not specifically for each substance, which leads to downcycling.**

Finally, **the birth of targets at European level for the recycled lithium content of new batteries is to be welcomed.** The initial target of a **minimum recycled lithium content** in batteries of 4% in 2030 and 10% in 2035[26] **has been revised upwards to 6% by 2031 and 12% by 2036. However, it is regrettable that the trilogue agreement put on the same level recycled lithium in end-of-life batteries with lithium** from "pre-consumption", i.e. **scraps from battery manufacturing**. While it is interesting to consider both types of recycling, as they can reinforce each other, it is also **important to distinguish the requirements**. The goal is to avoid a situation where the target for recycled lithium content in new batteries is achieved solely through the input of production scraps. Finally, the scrap is an input much more difficult to track and monitor.

These targets seem low when compared to the critical need to encourage the recycling of future spent batteries. Firstly, for environmental reasons: recycling the components of end-of-life LIBs has the potential to reduce energy consumption and CO_2 emissions$_2$[27] . **Secondly, recycling can slow down resource depletion.** Indeed, **resources**, **such as lithium, are finite,** and it is important to preserve what has already been extracted. To achieve this goal, there is a need for specific and efficient recycling and, in the meantime, organizing storage not to lose the **lithium in landfill sites**[28] or in road underlays or concrete.

[25] Final compromise text of the trilogue agreement on batteries. (2023). European trialogue.https://www.consilium.europa.eu/en/press/press-releases/2022/12/09/council-and-parliament-strike-provisional-deal-to-create-a-sustainable-life-cycle-for-batteries/

[26] Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on batteries and waste batteries, repealing Directive 2006/66/EC and amending Regulation (EU) 2019/1020, No° 2020/0353 (COD) (2020).

[27] Pinegar, H., & Smith, Y. R. (2019). Recycling of End-of-Life Lithium Ion Batteries, Part I: Commercial Processes. Journal of Sustainable Metallurgy, 5(3), 402-416.

[28] Pinegar, H., & Smith, Y. R. (2019). Recycling of End-of-Life Lithium Ion Batteries, Part I: Commercial Processes. Journal of Sustainable Metallurgy, 5(3), 402-416. In addition, this study points out that the disposal of LIBs under poor conditions can lead to health impacts.

	négaWatt scenario 2022	EU objectives
Collection rate of batteries	In 2030: 99%. In 2050: 99%.	**For the 'LMT'[29] :** In Dec. 2028: 51% In Dec. 2031: 61 **For used portable batteries:** In Dec.2023: 45% In Dec.2027: 63% In Dec. 2030: 73%. **No targets for cars**
Battery recycling rate	n/a[30]	By Dec. 2025: 65%. In Dec. 2030: 70%.
Lithium recycling rate	**In 2030: 80%.** **In 2050: 90%.**	**n/a**
Lithium recovery rate	n/a	In Dec. 2027: 50%. In Dec. 2031: 80%.
Recycled lithium content in a new battery	**In 2030: 20%.** In 2035: 30%. In 2050: 85%.	**In 2031: 6%.** In 2036: 12%.

Table 1: Comparison of EU and négaWatt targets in terms of collection, recycling of Li-ion batteries, recycling and recovery of lithium, and recycled content

Finally, it should be kept in mind that only the quantity available in the waste stream can be recycled. In a growing economy, this source is necessarily smaller than current consumption and the recycled content is limited. As a result, the recycled content of batteries is lower when the rate of growth in accelerates!

Sufficiency is therefore a necessary condition for high recycling targets.

Recycling is an essential lever to reduce the pressure on extraction and to avoid losing the resource contained in objects at the end of their life, but it will not be enough to satisfy all our needs ("closing the loop") as long as our needs are growing!

[29] LMT, "light means of transport", are wheeled vehicles equipped with an electric motor of less than 750 watts, on which passengers are seated while the vehicle is in motion and which can be propelled by the electric motor alone or by a combination of motor and human power. These are broadly defined as electric two-wheelers.

[30] The model takes into account a share of battery remanufacturing in the material balance. However, there is no target set in terms of battery recycling rates as such, mainly because not all battery materials are included in the material model.

Towards an increase in proven reserves?

The finiteness of resources and the importance of preserving the lithium contained in end-of-life objects is a major concern. However, when it comes to resource depletion, a common objection is that proven reserves are set to increase. Indeed, in three years, these reserves have increased from 14[31] to 22 million tons today[32] . Because of the growing but relatively recent interest in lithium, it is easy to anticipate further increases in this estimate in the coming years, as has been the case for oil. This increase is partly due to new discoveries and technological breakthroughs in exploitation techniques. This is currently being seen in the explosion of lithium exploration and exploitation projects around the world, even if we must remain cautious about their actual feasibility, with many projects already having proved to be unworkable.

However, this increase in reserves is also because resources already known - which were considered unexploitable yesterday for economic reasons, but also sometimes for social or environmental reasons - may be considered for exploitation tomorrow. This greater tolerance to potentially impactful projects can be seen with the emergence of projects such as that of the European Union Ciran[33] .

The question is: how far do we want to mine? **The evaluation of reserves does not take into account the health-related, social and environmental damage caused by lithium extraction.** Do we have to reproduce the very mistakes we did with oil? It is technically possible to extract lithium at ever lower grades, but the impacts will be significant.

This exponentially increasing exploitation will be at the risk of overexploiting water resources, permanently polluting the soil and contributing to the loss of biodiversity[34] and the displacement of local populations. **Is it not more reasonable and economical to anticipate and encourage a more sufficient and diversified mobility?**

[31] Mineral Commodity Summaries 2019. (2019). USGS.

[32] Mineral Commodity Summaries 2022. (2022). USGS.

[33] The EU is funding a project to investigate the potential for extraction of critical raw materials in protected areas. (2023, January 16). Background.

[34] Sonter, Laura J., Marie C. Dade, James E. M. Watson, and Rick K. Valenta. 2020. "Renewable Energy Production Will Exacerbate Mining Threats to Biodiversity. Nature Communications 11(1):4174. doi: 10.1038/s41467-020-17928-5.

The négaWatt scenario: towards a moderate use of lithium

The négaWatt Association has carried out an evaluation of the lithium requirements of various mobility schemes in its latest scenario for France (2022). It has developed a dynamic simulation model that integrates the growth of the electric vehicle fleet, battery technology, battery maintenance, the evolution of lithium recycling techniques, and the evolution of end-of-life batteries stock.

In the négaWatt scenario, the cumulative need for lithium from extraction by 2050 is compared with the share of the world's proven reserve that can be fairly allocated to the French population. Indeed, to guarantee equity and global justice, négaWatt considers that France should not consume more than its share of the world population. The aim is to ensure an equal level of access to sustainable mobility for all, which is a prerequisite for the fight against climate change.

As France's share of the world population is 0.86%, the volume of proven lithium reserves allocated to us is 189,000 tons.

Faced with the urgent need to move away from dependence on fossil fuels, there are several alternatives for the motorization of cars:

- 100% electric vehicles that require 300 to 600 kg of batteries (including 5 to 10 kg of lithium) for compact to SUVs cars[35] compared to 50 to 100 kg of batteries for microcars (the whole microcar is around 500 kg). To date, only LIBs can provide the necessary power.
- Thermal vehicles running on bioethanol, but this requires an increase in dedicated agricultural land (900,000 ha today), or biomethane, which requires the development of chemical and biological methanation, and pyro-gasification.
- Hydrogen-powered vehicles are unlikely to be economically feasible for the private vehicle and for the associated infrastructure (transport, distribution, refuelling). The efficiency is lower than an electric motor vehicle with a battery and this technology relies on a critical material, platinum.
- Finally, plug-in hybrids, provided of course that the auxiliary fuel is emission-free, which is the case with bioNGV[36] . In this case, the battery weighs only 70 kg, which reduces the strain on materials such as lithium and cobalt.

In the 2022 négaWatt scenario, the use of hydrogen is reserved for certain regional trains on non-electrified lines, and for a limited share of buses and heavy goods vehicles. Moreover, cars running on bioNGV alone are not envisaged: this fuel is only used in hybrid solutions.

In addition to the choice of motorization, it is essential to consider the levers leading to a diminution of demand in the field of mobility. Figure 5 presents simulations that vary the assumptions on the presence or absence of sufficiency measures and on the diversification of energy carriers[37] .

The measures are as follows:

- **Organizational sufficiency** consists in creating the conditions for moderating our travel needs: land-use planning to reduce the distances of our daily travels (be it going to work, shop, or leisure activities), development of teleworking, etc.
- **Dimensional sufficiency** concerns the correct sizing of equipment in relation to its conditions of use: limiting the size and weight of cars, and therefore of batteries, according to their use, limiting the range of vehicles so that gains in battery performance result in a reduction in their size and not in an increase in the number of kilometres travelled.
- **Sufficiency of use** regarding the proper use of equipment to reduce consumption: limiting speed to reduce consumption, promoting alternatives to the private car (soft modes of transport, teleworking, etc.);
- **Collaborative sufficiency** based upon a logic of pooling equipment and their use: strongly develop the public transport offer, carpooling and carsharing.

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[35] Including maintenance. These figures depend on the model: about 300 kg for the Renault ZOE, between 350 and 450 kg for a Tesla Model 3, about 600 kg for an electric SUV (100 kWh capacity) and about 100 kg for a Renault Twizy (a microcar). See Figure 7.

[36] Natural Gas for Vehicles

[37] Energy carriers are the various means of supplying energy to the vehicle. See in particular our note on the subject: People's mobility and energy carriers. (2018). NégaWatt Association. https://négaWatt.org/Mobilite-des-personnes-et-vecteurs-energetiques

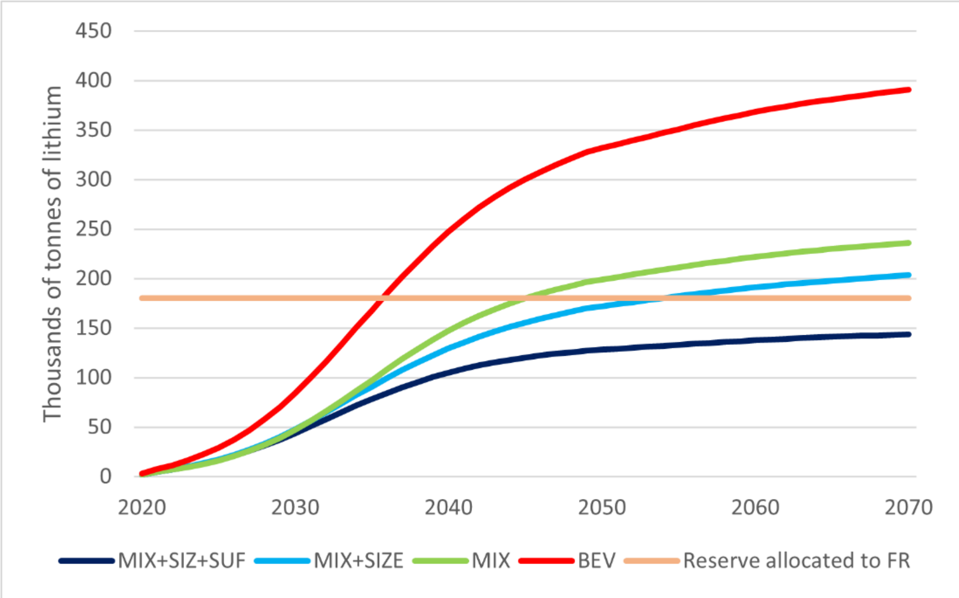

Figure 5: Cumulative footprint of lithium consumption under different mobility scenarios in France, compared to the 189,000 tons reserve allocated to France

BEV scenario:
"All-electric" scenario in which the entire fleet of passenger cars, light commercial vehicles and heavy goods vehicles are battery electric by 2050. No major sufficiency assumptions are considered.

MIX scenario:
Scenario of diversification of energy carriers. Most cars are electric (~70% of VKT[38]) or bioNGV rechargeable hybrids (~30% of VKT) and most heavy goods vehicles are bioNGV. No major sufficiency assumptions are considered.

MIX+SIZE scenario:
Scenario adding assumptions of dimensional sufficiency to the MIX scenario. Growth of electric microcars with small batteries (23% of pkm[39] in 2050).

MIX+SIZE+SUF i.e. négaWatt scenario:
Scenario adding assumptions of sufficiency of use, collaborative sufficiency and organizational sufficiency to the MIX + SIZE scenario.

The BEV simulation[40] corresponds to a mobility choice where the current fleet of vehicles is replaced by **100% electric mobility without any assumptions on sufficiency. It is clear that this scenario is not sustainable:** the lithium reserve allocated to France would be exhausted as early as 2035, despite significant efforts in terms of recycling.

Then, it is necessary to propose a diversification of energy carriers for each type of vehicle, which is summarized in Figure 6. Except for city cars, whose use in the city makes it possible to make a large place for microcars, in the MIX scenario compact and mid-size cars (B to D-segments) and commercial vehicles make a large place for hybridization where electricity is used alongside bioNGV. For heavy goods vehicles, electricity only accounts for 18% of the fleet, with the rest mainly using bioNGV.

[38] VKT: *Vehicle Kilometres Travelled* - use of a vehicle over one kilometer. Daily VKT are estimated by multiplying 24-hour average annual weekday traffic volumes by single centre-line length of the primary roadways. This is a measure of the actual use of vehicles, from which the energy consumption (and emissions) can be deduced by multiplying by an efficiency per km (kWh/VKT). We can also deduce the average intensity of use per vehicle by dividing it by the fleet (number of vehicles in circulation), which we can then use to determine the rate of renewal of the vehicle fleet.

[39] Pkm: passengers.kilometre

[40] BEV: *Battery Electric Vehicle,* to be distinguished from hybrid electric vehicles (HEV).

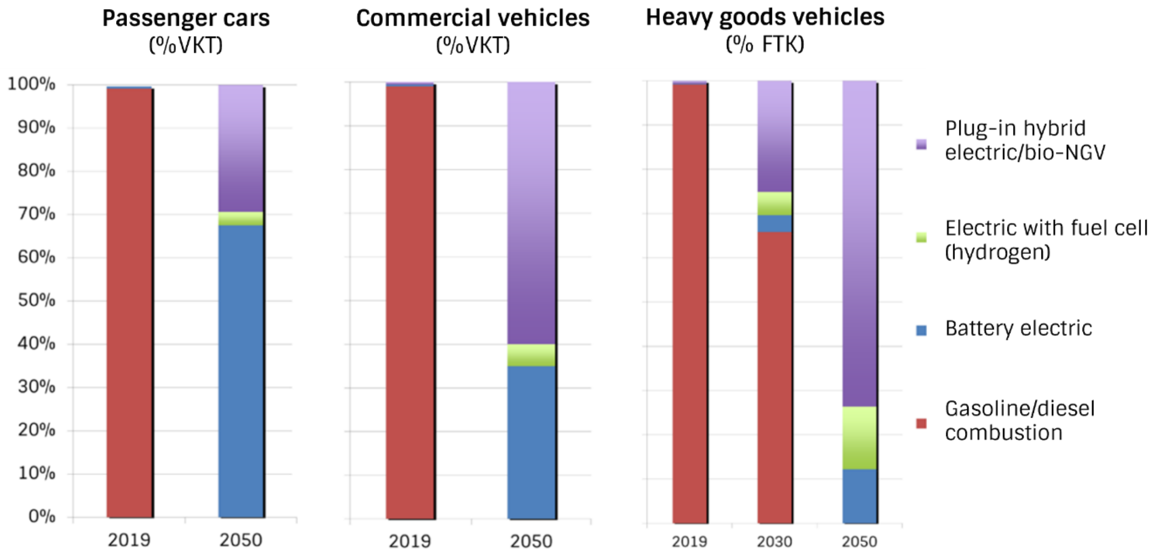

Figure 6: Distribution of the energy carriers mix used for each type of vehicle in 2050 according to the 2022 négaWatt scenario (MIX, MIX+SIZE, and MIX+SIZE+SUF scenario in Figure 5) ; FTK : Freight Tonne Kilometres

The European agreement to achieve zero-emission road mobility by 2035 has set a target of a 100% reduction in direct emissions for the entire EU fleet compared to 2021 for new passenger cars and light commercial vehicles[41] . **The ambition of this measure to reduce CO_2 emissions of vehicles[42] is to be welcomed, and finally sets ambitious targets for combating climate change.**

However, this agreement does not address the issue of the criticality of materials and the social and environmental impacts of extracting and refining the elements needed for the electrification of the car fleet (lithium, which is the subject of this note, but we can also mention cobalt, nickel, neodymium, etc.). **The analyses of the négaWatt Association show that it is necessary to consider both the transition in mobility to combat climate change and the economic** (linked to production capacity and reserves), **ecological and health impacts** related to the considerable increase in the consumption of metallic resources. To this end we should **act on two levels: to implement sufficiency measures and to diversify the alternative energy carriers to fossil fuels**.

These considerations lead us to believe that the **contribution of bioNGV and bioNGV hybrid vehicle to tackle the challenges of electric mobility has been largely underestimated**.

Figure 5 shows that **the MIX scenario of diversification of energy carriers**, with the use of bioNGV, **greatly reduces the threat to lithium compared to an all-electric BEV scenario.** However, despite a better result than the **BEV** simulation, the **quota limit of the lithium reserve allocated to France is exceeded from 2045 onwards.**

To tackle this issue and, more broadly, to address the energy and climate challenge, the négaWatt scenario has examined the effect of better matching the size of vehicles to their use. Today, a car is bought according to its most intensive use (for example, going on holiday), which leads to oversized cars for the most frequent uses (going to work alone or shopping), not to mention its downtime.

We can imagine a change in usage to reconcile the fight against climate change, the preservation of biodiversity and the sustainability of resources. For example, the use of small city cars (microcars type) - for households that need to have them - with reasonable range for inter-city or short-distance travel and, in addition, a fleet of car-sharing of compact and mid-size cars (B to D-segments), used more occasionally, for inter-city travel.

The battery of a mid-size car is 5 times heavier than that of a microcar, thus the need to emphasize and support the development of said microcars. **In the négaWatt scenario, microcars reach a 23% market share in 2050** and the consequence on materials is illustrated by the **MIX+SIZE** scenario in Figure 5. This corresponds to **a**

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[41] "On 27 October 2022, the co-legislators reached a trialogue agreement on the proposal, confirming the overall ambition of the Commission's proposal. Coreper approved the agreed text on 16 November 2022 and the ENVI Committee approved it on 1er December 2022." from: Revision of CO2 emission performance standards for cars and vans, as part of the European Green Deal | Legislative Train Schedule. (2022, December 15). *European Parliament*. See also: Agreement on zero emission target for cars and vans by 2035 | News | European Parliament. (2022, October 27). [Press release]. *European Parliament*.

[42] Nevertheless, it is 'at the tailpipe' emissions rather than over the entire life cycle of vehicles.

saving of almost 30,000 tons of lithium by 2050 and a postponement of the fateful date of exhaustion of the reserve to 2055.

Finally, other sufficiency levers exist which, combined with the sufficiency measures on the size of cars and the diversification of energy carriers, lead to the **négaWatt** scenario (**MIX+SIZE+SUFF**), represented in figure 5.

These complementary sufficiency measures consist firstly of reducing our travel (through teleworking, for example) and/or making use of public transport, cycling or walking whenever possible. **According to the négaWatt 2022 scenario, between 2020 and 2050, the number of kilometres travelled by car per inhabitant falls from 12,000 to 7,300 km/year.**

Moreover, car-sharing reduces car use and the need to manufacture new cars. In the négaWatt scenario, between 2020 and 2050, the average occupancy rate per vehicle increases from 1.7 to 2.3.

Finally, the scenario predicts that the rate of car ownership in households will be reduced by 30% by 2050, thanks in particular to car-sharing and the development of active modes of transport and public transport, which makes the purchase of a car economically unattractive.

In the French case, the **négaWatt** scenario (**MIX+SIZE+SUFF**) **would make it possible to limit the consumption of lithium to 128,000 tonnes from 2020 to 2050 instead of 340,000 tonnes in the full BEV simulation without any sufficiency or energy carrier mix measures.**

When studying the impact of the négaWatt scenario on resource consumption, we **extended the trends of the négaWatt scenario (MIX+SIZE+SUFF) to 2070, confirming that only this trajectory does not compromise our lithium footprint and allows a truly sustainable future**.

Putting the French lithium mine project in the Allier into perspective

A lithium mine project at Echassières in the Allier region of France[43] , which might become the largest mine in Europe, has recently received extensive media coverage. Imerys, the company behind the project, has estimated that its annual production will reach 34,000 tons of lithium hydroxide from 2028 onwards, i.e. around 10,000 tons of lithium metal[44] for a period of 25 years. The estimated resource on this site represents 95%[45] of the possible resources evaluated by the BRGM in France[46] and would be approximately 248,000 tons of lithium metal.

It should be remembered that these figures must be treated with great caution, since the company is still in the exploration phase and that we are talking of inferred resources, **i.e. the quantification of the resource is still very uncertain.** Indeed, Inferred Mineral Resources, the stage now reached by Imerys, are that part of a Mineral Resource where the quantity and grade are estimated based on geological evidence and **limited sampling.** Unlike **Indicated** Mineral Resources (which Imerys claims to reacg in 2023), continuity of grade is assumed, but not verified. **Inferred Mineral Resources have too low a confidence level to be converted to reserves, the concept used throughout this note.** To continue this call for caution, we also note that the production figure of 10,000 tons of lithium metal per annum for 25 years would correspond to the announced resource only if the production yield of each stage were 100% (which is obviously impossible).

That said, if Imerys' 2022 estimates of inferred lithium resources at the Echassières mine were to be confirmed by ongoing exploration, they **could potentially meet the cumulative lithium needs of the négaWatt scenario, estimated at 128,000 tons of lithium by 2050, but by no means an all-electric scenario without sufficiency measures** (BEV scenario in Figure 5). Indeed, the Imerys press release states that the 25-year operation of the mine would allow 700,000 electric vehicles/year to be powered. **What does this figure of 700,000 vehicles per year calculated by Imerys correspond to? Presumably to autonomous SUV, as the table below shows. However, as we saw earlier, if only electric mid-size cars** (D-segments) **were produced, and it is obviously worse with SUVs, the proven reserves of lithium would quickly be exhausted on a global scale.**

	Battery capacity	Range (WLTP)	Number of vehicles
SUV: J-segment (2 200 kg)	80 kWh	500 km	800 000
Large cars: D-segment (1 700 kg)	60 kWh	440 km	1 100 000
Small to medium cars: B and C-segment (1200 kg)	40 kWh	320 km	1 600 000
Microcar (500 kg)	6 kWh	70 km	11 000 000
Electric bicycle (e-bike)	0.5 kWh	~ 80 km	131 000 000

Figure 7: Number of vehicles that could be produced with 10,000 tons of lithium metal depending on the type of vehicle and the associated battery.

NB: 1) the production figure of 10,000 tons of lithium per year is currently highly uncertain 2) Data are indicative and may vary according to the model.

[43] Vif, J.-Y. (2022, October 24). A first lithium mine is to be exploited in France, with the ambition of equipping 700,000 vehicles with batteries per year. Le Monde.

[44] See conversion table at the end of this note. In this note all data are given in lithium metal, unless otherwise noted.

[45] Excluding deposits in protected areas such as Natura 2000 in Tréguennec (Finistère)

[46] BRGM (2021): https://infoterre.brgm.fr/rapports/RP-71133-FR.pdf (see page 33)

While the question of how to supply lithium and other metals must be addressed at the European and French levels, **questions revolving around the uses that should be favoured in a finite world must also be addressed. This raises a major public policy question: what modes of consumption are sustainable and how can they be promoted?** Although this question seems to be absent from the debate on resources such as lithium, many mechanisms could be envisaged to encourage sufficiency in various forms, as mentioned in the previous paragraph on mobility, but also at the level of manufacturers to promote the production of small cars and batteries. **This would complement ambitious policies on the collection of end-of-life batteries, on recycling** and on increasing the recycled lithium content in new batteries compared to those currently being negotiated at the European level.

Another point is that the communication surrounding the mine project in the Allier region highlights the low environmental impact. **However, there is currently not enough information to make a judgement on the real environmental and health impact of this large-scale project, as we are very much upstream of the project development.** The detailed operational plan has not been decided, the volume of mining waste is not known, nor is its potential toxicity. Waste storage facilities are not included in the current communication plan, etc. **In short, an environmental assessment of the project has not been carried out, and this is the only way to provide a basis for analysing the environmental and health impacts.**

It should be noted that there are also other lithium exploration and exploitation projects in which industrial players are positioned in France in the Rhine basin. This is a completely different type of exploitation: extraction of geothermal brine at a depth of 2,500-3,000 meters to combine heat production (high-energy geothermal energy) and lithium production. This note does not detail these other projects.

Finally, on the question of sovereignty, it should be remembered that the integrated chain approach is the only one that allows complete autonomy and that the installation on our territory of various links in the chain is no guarantee that each link is independent of external imports. It seems unlikely that a complete vertical integration of the lithium chain is realistic in the short term. Moreover, **France will not be able to be entirely autonomous in all sectors,** such as cobalt and nickel, which are also present in LIBs, and neodymium in permanent magnet electric motors, not to mention metal sectors outside the automotive sector. While the desire to acquire part of the production resources for the sectors linked to the ecological transition seems realistic and necessary, is complete autonomy for France or EU even desirable? Shouldn't the world's proven lithium reserves, which can be exploited under good ecological and social conditions, be considered as far as possible in an approach of equity and solidarity on a global scale?

Beyond the aspect of sovereignty, if relocation is envisaged for ecological reasons, it should not be forgotten that, **even with strong sufficiency measures, imports will continue in many metal sectors**. **It is therefore essential that public authorities ensure that metal-producing and consuming industries comply with international social and environmental standards**, namely via the French Duty of Vigilance Law, enacted on the 27th of March 2017, the draft European directive, i.e. the Commission's proposal for a "corporate sustainability due diligence directive", published on the 23th of February 2022, currently under discussion and the draft UN treaty on multinationals and human rights. These regulations, existing or to come, must be imposed on French and EU companies that source lithium from abroad.

Furthermore, it seems important, if Europe wants to prove its commitment to ecology, **to start by banning mining in protected areas on European soil**, contrary to the current trend.

Conclusion

To meet the challenges of climate change and the urgent need to achieve carbon neutrality, the electric vehicle is unavoidable. Nevertheless, **the unplanning** of its use, i.e. without deciding collectively on a limit for the **use of the** resources involved, **will lead to major concerns** - particularly in the lithium sector, but also for other resources implied as cobalt - whether **in economic, social or environmental terms**, with the risk of transferring the impact of climate change to issues of over-consumption of water resources, soil artificialization, toxicity and loss of biodiversity.

The answer to this new challenge is not out of reach, but it requires to associate this "electrical revolution" with "a revolution of our means of transportation and vehicles", combining sufficiency measures and diversification of energy carriers. This is what the négaWatt scenario proposes with a softer, more participative mobility that leaves a significant place for bioNGV.

Finally, the case of lithium shows the need to analyse and plan the ecological transition by taking into account its impact in terms of production and consumption of materials, even those which are not considered critical today.

Annex

Conversion table for lithium

		Li	Li_2O	Li_2CO_3	LiOH
Pure lithium metal	Li	1	2.15	5.32	3.45
Lithium oxide	Li_2O	0.46	1	2.47	1.60
Lithium carbonate	Li_2CO_3	0.19	0.40	1	0.65
Lithium hydroxide	LiOH	0.29	0.62	1.54	1

Reading:

- 1t Li metal converts to 3.45t LiOH or 2.15t Li_2O
- 1t LiOH contains 0.29t Li metal