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***ABSTRACT***

*PhD Thesis*

***CRITICALITY OF MINERALOGICAL RESOURCES  
IMPLIED IN THE TRANSITION TOWARDS  
ELECTROMOBILITY***

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This study is based on official texts, calculations from various organizations recognized at national and international level, discussions with other researchers and observations drawn from my professional experience and previous research. It aims to ensure that the resilience of the European automotive sector is effective in this transition towards electromobility through a systemic approach.

The main goal of the thesis is to demonstrate the critical role of minerals in the double transition – the ecological one - related mainly to electrification of transports and the second one, connected with - the digital one-, both susceptible to produce a substantial crisis in the minerals supply.

In a first part, we studied why electromobility is in a rejuvenation phase (I).

In a second part, we demonstrated how this double transition imposes the emergence of automobiles 3.0 (II).

In the third part, we will observe how the three main industrial powers of the automotive world are reacting to this new situation (III).

In the fourth part (IV) some of the statements and remarks will be demonstrated through mathematical models.

Electromobility is an industrial transition initiated in different ways by several political and industrial leaders. This transition, which is actually twofold in Europe since it intends to combine a shift towards the ecological transition and the digital transition, requires a very large sum of financial, technical and mineralogical resources and the consideration of psychological elements which can accelerate or delay the application of the program. Electromobile is at the convergence of the two transitions, and admirably serves as a witness for the policy expected in the coming years.

In this race for the electrification of vehicle fleets, many governments have imposed on themselves to respect a timetable based on environmental considerations. Incidentally, this is a shift of automotive industrial power from the Atlantic to the Pacific. This transition has been prepared for longer in Asia, and more particularly in China and to a lesser extent in the United States, driven by Tesla, which offers these countries a real competitive advantage.

Although hybridization is the preferred method in Europe, European industrial manufacturers are obliged in order to survive to ally themselves, to merge, to transform or to disappear. The situation of polycrisis that the European Union has been experiencing for several years has highlighted the fragility of its supply networks as well as its industrial weakness, including the mining sector which it is trying to upgrade. A question remains to be asked despite everything: is it wise to combine two simultaneous transitions at a time when the feverishness of the different member states is obvious?

The automotive industry (understood in the broad sense, i.e. manufacturers, equipment manufacturers, subcontractors, garages, associated and related service companies, etc.) is a fairly convincing demonstrator for verifying that electromobility at the crossroads of the two transitions poses serious challenges. These challenges are not insurmountable but they demand a mineralogical tribute for the set objective. And, until any valuable substitutes could be found, many mineralogical elements will continue to be strategically coveted.

The modern electromobile now needs two fuels: electricity and data. And to allow it to operate while meeting these two requirements, the automotive industry is forced to carry out a bulimia of mineralogical resources. However, the more complex a manufactured product, the more likely it is to be affected by vulnerabilities, material and immaterial.

The member countries of the European Union have a real challenge to preserve and improve the automotive industry. The solutions mentioned in the development which have been put forward are medium and long term but do not call into question the general policy : these solutions are a series of accommodations taken *a posteriori*.

However, there would be every interest in giving priority to two axes: the first being technological neutrality; the second being technological sobriety.

The official speech of the European authorities is above all anxiety-provoking and starts from a negative principle, that the land vehicle is fundamentally accident-prone and polluting by nature. “Whilst mobility brings many benefits for its users, it is not without costs for our society. These include greenhouse gas emissions, air, noise and water pollution, but also accidents and road crashes, congestion, and biodiversity loss – all of which affect our health and wellbeing. Past efforts and policy measures have not yet sufficiently addressed these costs.”.[206]

They omit to specify that the engineering made possible to reduce the cost, the danger and the pollution substantially since the first initiatives of the 1950s. Even more embarrassing, there is no audit on these misdeeds by combining energy transition and digital transition in the transport field. The benefits of electromobility are real, but they also have a dark side that should not be hidden. Scientific honesty must precisely demonstrate that electromobility generates benefits and harms. This solution is technically possible, but it cannot substitute for other researches.

This is where technology neutrality is at stake. If the European Parliament has forced all-electric, especially battery-powered models, it has left only a small window for alternative solutions.

Biofuels and E-fuels are in a probationary period till 2026, which means that they may be able to integrate the EU discharge for vehicles authorized for sale. The principle is nevertheless debatable because it is based on a negative *a priori*.

The addition of a plethora of electronic and digital devices also harms this transition because this trend forces the electric vehicle to use more metals, it weighs it down, it complicates it and finally, it exposes it to more vulnerabilities. Because if there was in the past a real trend from the world of sports competition and then from premium vehicles to benefit more and more from electronic aids and digital control, nowadays legal obligations have accentuated the phenomenon in the long term. And in return, the vehicle requires even more metals and alloys to reduce this overweight. The decarbonization of transport will inexorably result in their metallization, both directly (transport electrification) and indirectly (energy production and delivery). Technological sobriety should not be imposed, but it should not be restricted either. For the time being, it is inflation that is taking hold in our cabins, and the success of SUVs is a consequence of this imposed trend.

The technological race takes new vehicles into an admirable technological complexity but in the same time subject to increased risk potential on the mechanical, electronic and digital levels as well as in the supply of materials now considered critical. These electronic and digital artifices are more and more a matter of remote technological warfare than of satisfying real needs. And electromobility is becoming heavily dependent on this phenomenon within strong technological thrust in our cabins

Furthermore, adorning the electromobile with all the virtues could paradoxically expose it to a backfire, as happened for diesel, formerly favoured by European authorities and its member

countries until 2015. If an electrogate on the model of the Dieselgate can be avoided, it will be by understanding and providing information on the advantages and disadvantages of this mode of motorization [206].

It emerges from the many European texts studied that the subject is more of the order of declamatory than of a rational organizational approach. “Greening mobility must be the new licence for the transport sector to grow [...] by abundant recharging and refuelling infrastructure for zero-emission vehicles and supply of renewable and low-carbon fuels. Digitalisation will become an indispensable driver for the modernisation of the entire system, making it seamless and more efficient [...] thereby maintaining the EU’s leadership in transport equipment manufacturing and services and improving our global competitiveness through efficient and resilient logistics chains.”.[207]. The strategy plans that have succeeded in recent years are cause for concern since they were produced after deciding on the double transition. Electromobility is a consequence of this approach to the situation *a posteriori*. Electromobility is a solution that was, from the start, exclusive of any other. It's a transition that wasn't designed with the support of an ecosystem but by creating an ecosystem from scratch. Grants and action plans cannot solve everything.

In this transition to electromobility, Chinese and American players are also subject to difficulties, but they have a dynamic internal market where the transition can take place in stages, whereas in Europe it is a monolithic transition without regard for national and regional disparities. Even worse, American and Chinese competitors have a solid and plethoric ecosystem for the digital part, while the European one is smaller and struggles to avoid predation. In China, the government plays the role of the orchestra conductor ; in the United States Tesla plays the role of locomotive ; In Europe, the Commission plays the role of the whip.

The European Commission presented a draft text, the *Critical Raw Materials Act*, on March 16, 2023, then registered in the Official Journal of the European Union on 3 May 2024.[208] This official text recalls the importance of the mining sector and proposes to strengthen the different stages of the European critical raw materials value chain. However, the European body reaffirms its desire to link the two transitions: “*Without a secure supply of critical raw materials, the Union will not be able to meet its objective for a green and digital future... The measures on Strategic Projects focus on strategic raw materials (SRMs) to ensure that the Regulation brings*

*within its scope the materials that are the most needed to achieve the EU's objectives for the green and digital transitions as well as for increased resilience and security.*". Unfortunately, no assessment is drawn from the measurements already carried out or on the potential for a discrepancy. This lack of a balance sheet is harmful because it avoids the difficulties already encountered and to come.

Due to the historical industrial specificities of the member countries of the European Union, the transition to electromobility must be a choice based on efficiency, sustainability, viability and acceptability. But it must remain a choice, and not a policy based on constraint and decisional rigidity. Otherwise, it will no longer be a solution but a headlong rush.