CRITICAL RAW MATERIALS AND TRANSPORTATION SECTOR ELECTRIFICATION: A DETAILED BOTTOM-UP ANALYSIS IN WORLD TRANSPORT

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Overview

The aim of this article is to study the impact of a massive diffusion of electric vehicles in the world transportation sector on the lithium market. Lithium, like other strategic materials, has found new markets in the context of the energy transition. Hence, the capacity of those strategic materials to supply these new markets can be questioned. To achieve this goal, we have developed the first detailed global bottom-up energy model, TIAM-IFPEN (Times Integrated Assessment Model-IFPEN) with an endogenous disaggregated life-cycle inventories. It would clearly assess the dynamic criticality of strategic materials according to the optimal technology paths with environmental and/or energy solicitations through different approaches: geological, geopolitical, and economic towards a sustainable development. Four scenarios have been run taking into account two climate scenarios (4°C and 2°C) with two shapes of mobility each: a high mobility where we assume the impact of urban dispersal with a huge car dependence/usage, and a low mobility where the idea of a sustainability in mobility is assumed. The penetration of electric vehicle (EV) at the global level would push the demand of cumulated lithium but the results show us an absence of geological criticality. Nevertheless, they have clearly highlighted other different forms of vulnerabilities, whether economic, industrial, geopolitical or environmental. A discussion about the future risk factors applied to the lithium market has been also done at a regional scale to analyse more in-depth the impact of the future global fleet development on lithium market. Our study of this particular strategic material shows that the model could be a useful decision-making tool for assessing future raw material market stresses along with energy transition and could be extended to other critical raw materials for more efficient regional and sectorial screening.

Methods

We use the TIAM-IFPEN (TIMES (The Integrated MARKAL-EFOM System) Integrated Assessment Model) model, a technology rich bottom-up cost optimization belonging to the MARKAL (MARKet Allocation model) family model. Energy supply, demand and market dynamics are modelled in order to represent energy dynamics over a long-term, multi-period time horizon at a local, national, multi-regional, or global level. For the purpose of the present study, we run four scenarios where we have considered two climate scenarios with two different type of mobility each in order to assess the impact on the lithium market along with the transportation electrification:

- Scen 4D which is consistent with limiting the expected global average temperature increase to 4°C above pre-industrial levels by 2100.
- Scen 2D which is a more ambitious scenario, which translates the climate objectives of limiting global warming to 2°C by 2100.

In each climate scenario, two shape of mobility have been considered as abovementioned:

- Hypothesis of a High mobility where we assume the impact of urban dispersal, a worldwide phenomenon, on mobility and travel as well as the influence of urban land coverage on travel where we keep on having a huge car dependency and usage.
- Hypothesis of a Low mobility where the idea of a sustainability in mobility is assumed. This means taking into account social, economic and institutional dimensions to move beyond a focus on ecology and the natural environment. This assumption implies more compact cities, underpins an integrated approach to urban land-use and transport planning and investment, and gives priority to sustainable modes of mobility such as public and non-motorized transport as seen in **Erreur ! Source du renvoi introuvable.** with the bus and minibus travel demands.

Results

Cumulative demand for lithium from 2005-2050 is estimated at 7.5 and 8.5 Mt respectively in the low and high mobility of the 4°C scenario, while it reaches 19.7 and 24.7 Mt in the case of the 2°C scenario. Demand is driven globally by China, Europe, India and USA in both climate scenarios. A comparison of cumulative lithium consumption between 2005 and 2050 with current reserves (16 Mt in 2017) provides information about the level of criticality of lithium. It shows that only 2°C scenarios will certainly have a cumulative lithium consumption higher than the current level of lithium reserves. On the contrary, in the 4°C for any shape of mobility, the cumulated lithium demand is far under the current lithium reserves 2017. The safety margin (ratio of the

cumulative consumption to the current resources) is decreasing in both climate scenarios as the lithium consumption follow the same trend as the penetration of EV. It fluctuates from 86% to 84% in the 4°C scenario according to the shape of mobility while it is falling from 63% to 53% in the most stringent climate scenario (2°C scenario).

Conclusions

The scenarios developed in this article tend to show that a high penetration of the EV worldwide could lead to a decrease in the lithium safety margin in the 2°C, the most stringent climate scenario, and an hyper mobility. This leeway varies from 86% to 84% respectively in the 4°Cscenario with low mobility and high mobility while it is falling from 63% to 53% in the 2°C according to the shape of mobility. The demand of cumulated lithium in the 2°C with hyper mobility would reach by 2050 around 1.5 times the current level of lithium reserves. Therefore, it is likely that it will be technologically accessible by 2050 according to recent project announcements. However, long-term equilibrium dynamics in commodity markets tell us that the absence of geological criticality of reserves and resources does not hide different forms of vulnerability, whether economic, industrial, geopolitical or environmental.

Four major risks on the lithium market have been thus identified according to our modelling results:

- Uncertainties about the market's ability to meet the new and growing demand on time
- Uncertainties related to the environmental impacts of lithium production
- Uncertainties about the commercial strategy of large lithium consumers (especially China)
- Uncertainties about the consequences of national strategies in the lithium triangle

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