***PROSPECTIVE IN THE GLOBAL VALUE OF LITHIUM ION BATTERY: A CRITICICALITY ANALYSIS***

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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-ion battery. All the material components of the lithium-ion battery (copper, nickel, cobalt and lithium) have 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 nickel, cobalt, lithium and copper (present in the car body) 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 BAU mobility where we assume a continuous increase of the ownership rate and a huge car dependence/usage, and a Sustainable mobility where the idea of a sustainability in mobility is assumed due to stronger fiscal and regulatory policies. The penetration of electric vehicles (EVs) at the global level would push the demand of cumulative materials, and we explore the geological, economical and environmental criticality of each of them. A discussion about the future risk factors applied to these materials has been also done at the regional scale to analyse more in-depth the impact of the future global fleet development on these commodity markets. Our study shows that the model could be a useful decision-making tool for assessing future raw material market stresses 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 BAU 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 Sustainable 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 Fig. 8 with the bus and minibus travel demands.

## Results

Cumulative demand for copper, nickel, cobalt and lithium should registered a dynamic growth from 2020 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 materials extraction between 2005 and 2050 with current reserves and ressources provides information about the level of criticality of each materials. It shows that copper and cobalt criticality are expected to be higher than the level of criticiality observed for nickel and lithium.

Table 1 : Ratio of cumulative demand of strategic materials from 2005 to 2050 divided by proven resources registered in 2010

|  |  |  |
| --- | --- | --- |
|  | 4°C Scenario | 2°C Scenario |
| Cobalt  Cuivre  Lithium  Nickel | 62.2%  108.6%  17.1%  48.5% | 93.6%  130.3%  26%  56.6% |

Source: authors

## Conclusions

The scenarios developed in this article tend to show that among all the components of the electric vehicle, copper and cobalt tend to demonstrate a high level of criticality. High penetration of the EV worldwide could lead to a decrease in the materials safety margin in the 2°C, the most stringent climate scenario, and an hyper mobility. Public policies such as recycling and sustainable mobility could overcome part of this dynamic. Environmental issue such as water consumption in the mining industry should also be taken into account in the technological choices induced by the world-wide energy transition.

## References

Achzet, B., Helbig, C., 2013. How to evaluate raw material supply risks - an overview. Resour. Pol. 38, 435-447.

De Koning A., Kleijn R., Huppes G., Sprecher B., van Engelen G., Tukker A., 2018, Metal supply constraints for a low-carbon economy, Resources, Conseration and. Recycling Volume 129, p202-208.

Graedel, T.E., Reck, B.K., 2016. Six years of criticality assessments: what have we learned so far? J. Ind. Ecol. 20 (4), 692-699.

Habib K., Hamelin L., Wenzel H., 2016, A dynamic perspective of the geopolitical supply risk of metals, Journal of Cleaner Production, Volume 133, p850-858.

Hache E., 2017, Do renewable energies improve energy security in the long run?, International Economics, In Press.

Hache E., Seck G. S., Simoen M., 2018b, Electrification du parc automobile mondial et criticité du lithium à l’horizon 2050, ADEME (French Environment & Energy Management Agency)/IFPEN.

Hatayama H., Tahara K., 2018, Adopting an objective approach to criticality assessment: Learning from the past, Resources Policy, Volume 55, p96-102.

Helbig C., Bradshaw A. M., Wietschel L., Thorenz A., Tuma A., 2018, Supply risks associated with lithium-ion battery materials, Journal of Cleaner Production 172, pp274-286.

Helene Ystanes Føyn T., Kenneth Karlsson, Olexandr Balyk, Poul Erik Grohnhei, 2011, A global renewable energy system: A modelling exercise in ETSAP/TIAM, Applied Energy, Volume 88, p526-534.

International Energy Agency IEA, 2018, Global EV Outlook 2018: towards cross-model electrification.

International Renewable Energy Agency IRENA, 2018, Renewable Power Generation Costs in 2017.

Loulou R., Remme U., Kanudia A., Lehtila A., Goldstein G., 2016, Documentation for the TIMES model, ETSAP.

Loulou R., Goldstein G., Noble K., 2004, Documentation for the MARKAL family models, ETSAP.

Loulou, R., Labriet, M., 2008, ETSAP-TIAM: the TIMES integrated assessment model Part I: Model structure, Computational Management Science, Volume 5, Issue 1–2, pp. 7–40.

Miedema J. H., Moll H. C., 2013, Lithium availability in the EU27 for battery-driven vehicles: The impact of recycling and substitution on the confrontation between supply and demand until 2050, Resources Policy 38, pp204–211.

Moss R. L., Tzimas E., Kara H., Willis P., Kooroshy J., 2013, The potential risks from metals bottlenecks to the deployment of Strategic Energy Technologies, Energy Policy 55, pp556–564.

Speirs J., Contestabile M., Houari Y., Gross R., 2014, The future of lithium availability for electric vehicle batteries, Renewable and Sustainable Energy Reviews 35, pp183-193.

Van der Zwaan, B., Keppo, I., Johnsson, F., 2013. How to decarbonize the transport sector? Energy Policy Volume 61, p562–573.

Wang X., Gaustad G., Babbitt C. W., Richa K., 2014, Economies of scale for future lithium-ion battery recycling infrastructure, Resources Conservation and Recycling 83, pp53-62.

Yaksic, A., Tilton J., 2009, Using the cumulative availability curve to assess the threat of mineral depletion: The case of lithium, Resources Policy 34, pp185-194.

Yan Z., Du K., Yang Z., Deng M., 2017, Convergence or divergence? Understanding the global development trend of low-carbon technologies, Energy Policy 109, pp499–509.

Zeng X., Li J., Liu L., 2015, Solving spent lithium-ion battery problems in China: Opportunities and challenges, Renewable and Sustainable Energy Reviews 52, pp1759-1767.