Title: Comparative analysis of copper demand in different IAMs' carbon restriction scenarios

Summary

Mitigation options depend upon technologies that require energy and materials throughout their life cycle. Thus, with the energy transition underway, assessing its impacts throughout its production chain on the environment and society becomes crucial. This study aims to perform a comparative analysis of copper demand required in different IAMs climate policy scenarios Then, based on the projected copper demand for each scenario, a discussion is carried out on the feasibility of decarbonization scenarios considering the copper production constraints and its estimated reserves.

1. Introduction

There is a growing concern about the hidden impacts that deep decarbonization trajectories can bring to prevent the global average temperature from exceeding 2°C. Integrated Assessment Models (IAMs) have portrayed innumerable possible pathways by deploying innovative technologies for energy generation and carbon capture [1]. However, the impacts associated with the demand for materials that such technologies require are currently overlooked.

The materials are highly relevant for tackling climate change. They contribute to almost 25% of total global greenhouse gas (GHG) emissions [2]. They are likely to continue to grow in the coming decades due to their consumption being directly linked to income and population growth, mainly in developing countries[3]. This fact alone poses a challenge for decarbonization, decoupling material demand from population and income while respecting sustainable development goals. By including the materials required for the energy transition, the decarbonization pathway becomes even more challenging.

IAMs can model several potential pathways to achieve the objectives of the Paris agreement. However, only a few evaluate the influence of materials on the feasibility of low carbon scenarios. A growing body of literature has demonstrated the scientific community's efforts to calculate materials demand in several sectors and incorporate material flows and restrictions in IAMs [4–8]. Notwithstanding, materials modeling in energy systems still has a long way ahead since most articles are restricted to analyzing only a limited number of industries and usually separated from each other. In other words, efforts are still needed to integrate materials flows across all sectors considered in IAMs.

For this reason, this research evaluates the copper demand needed to manufacture renewable energy converters and the transmission network expansion considering various climate policy scenarios proposed by different IAMs. Additionally, this study aims to contribute to developing the materials satellite model to be linked with the Computable Framework For Energy and the Environment (COFFEE) global IAM[1].

2. Methods

The methodology proposed in this study encompasses two main steps, which are (i) the calculation of materials' demand for solar (photovoltaic and concentrated solar panels) and wind (onshore and offshore) plants and transmission lines and (ii) the estimation of material efficiency rates that stem from technological learning curves.

As illustrated in Figure 1, the first step of the methodology is to gather data from IAM scenarios database available in [9]. This database contains results from various IAMs according to different scenarios that considered distinct assumptions regarding nationally adopted climate policies and carbon budget limits, whether overshooting or not.

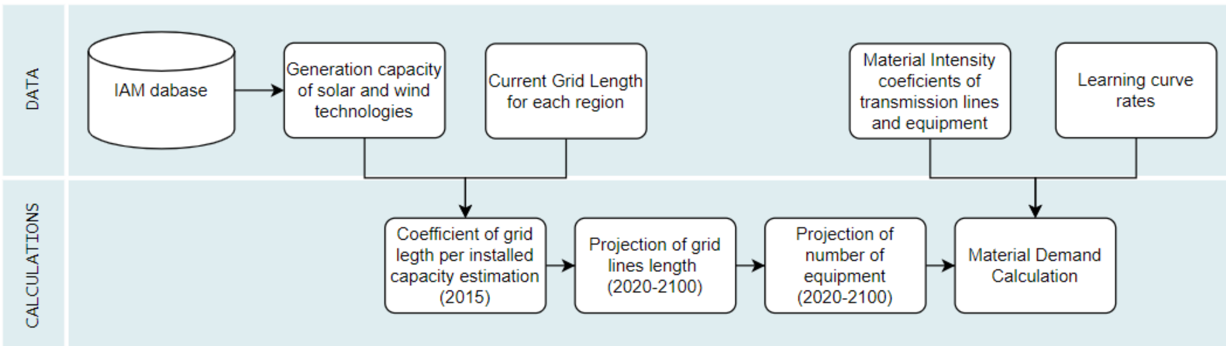


Figure 1:Methodology Flowchart

To determine the copper demand for each energy generation technology and the transmission infrastructure, renewable energy installed capacity split by region, scenario and period were multiplied by material intensity coefficients. It is noteworthy that these coefficients are specific for each technology to portray their differences regarding the use of copper. For instance, offshore wind farms are more intensive in copper, mainly due to Direct Drive generators and longer cables for towers than onshore grid connections[10]. Then, an annual reduction factor was applied to the copper intensity coefficient by calculating an exponential fit in learning curves data taken from the literature[11].

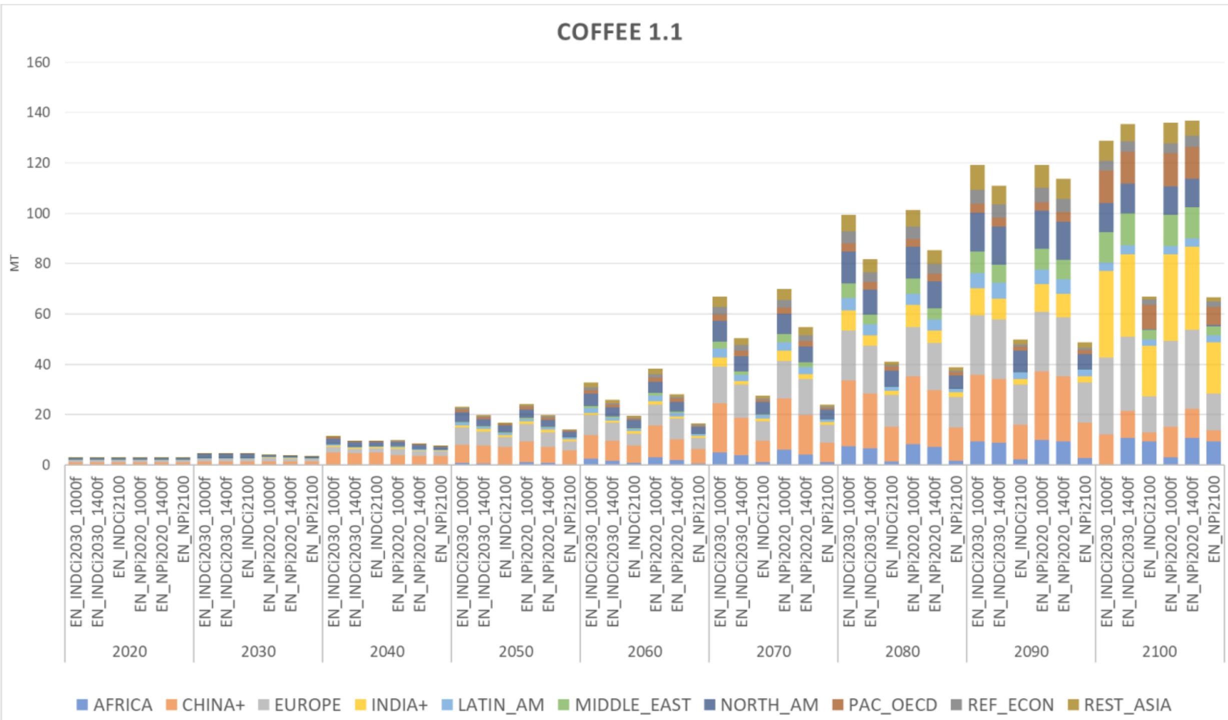
An additional intermediary analysis is carried out to project the required energy transmission infrastructure, particularly for the transmission sector. This estimate is made through a linear relationship between existing high voltage transmission lines in each region in 2015 and the installed capacity of each region for the same year. The length of medium voltage (MV) and low voltage (LV) lines were estimated using a ratio related to HV length[12]. Next, this coefficient was applied to the future installed capacity of different IAMs, resulting in grid line length per period. With these results, it is possible to estimate the number of transformers and substations needed to apply material intensity coefficients to estimate copper demand.

Finally, the copper demand results obtained for each scenario, region and IAM will be compared with the copper production capacity and estimated reserves to introduce a discussion regarding possible constraints of low carbon scenarios that may arise due to supply issues and copper scarcity.

3. Expected Results

The expected findings of this work may reveal a correlation between climate policy ambitions and renewable energy penetration rates. Materials demand growth is likely to be related to carbon budget restrictions because the higher the carbon concentration restriction, the greater the expected renewable energy installed capacity in most IAMs. Furthermore, it is likely that late actions scenarios may concentrate a greater copper demand in a short period of time, provoking supply restriction and possible impacts on carbon reduction target achievements.

Figure 2 provides a preliminary result of copper demand in the COFFEE model considering a range of scenarios[1] with different carbon emission constraints and climate policy assumptions. As shown in this figure, the requirement for copper in the COFFEE model is nearly insignificant until 2050. After this period, the demand rocketed considerably until the end of the century. Results for this model clearly show the association between carbon budget availability and renewable energy source deployment. In scenarios with no carbon budget constraint, copper's demand is less than half compared to other scenarios. The regions with the most significant need for copper are Europe and Africa, representing more than 60% of all global copper demanded.



4. Final Remarks

This study set out to critically examine the viability of deep decarbonization scenarios by estimating the demand for copper in renewable energy technologies and its associated transmission infrastructure for distinct low-carbon narratives. The authors reinforce the hypothesis that scenarios with carbon emissions restrictions can sharply increase the demand for materials and intensify geopolitical, social, environmental, and economic issues in different countries worldwide.

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[1] The scenarios that begin with "INDC" consider all the policies adopted by the signatory nations of the Paris Agreement and therefore include climate policies not yet applied today. On the other hand, "NPi" scenarios are those in which only current national policies are considered. In addition, some narratives have set limits on the global carbon budget. They are INDCi2030_1000f and NPi2020_1000f, in which the carbon budget allowed is 1000Gt, and INDCi2030_1400f and NPi2020_1400f allow a budget of 1400Gt.

Materials logistic and production infrastructure deployment is costly and constitutes typically long-term investments. Rates of renewable installation are significant as fast rates could lead to a skyrocketed consumption of materials in a short period, which may bring up supply restriction risks.

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