GHG emission reduction potential in the industrial sectors: comparison of IAM and sector model

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Background

Some industrial sectors, such as iron and steel and cement manufacturing, are considered difficult sectors to reduce GHG emissions, and the measures taken in these sectors will have a significant impact on the pathway to achieving the long-term temperature targets outlined in the Paris Agreement. Most integrated assessment models (IAMs) used to quantify climate change mitigation scenarios represent industrial sectors in an aggregated manner, making it difficult to consider detailed emission reduction measures in a specific industry. Mitigation scenarios have also been quantified using single-sector models. This type of model takes a sector-specific modeling approach and provide a detailed representation of the technologies, allowing the scenario estimation that consider a greater number of emission reduction measures in the sector of interest.

The purpose of this literature review is to compare climate change mitigation scenarios and how emission reduction technologies are represented between single-sector models and IAMs in industrial sectors where emission reductions are difficult, to examine directions for future development of IAMs.

Methodology

In this study, we used the Web of Science to search literature published from 2015 to June 2024 using the keywords “Decarbonization”, ”Carbon neutralization”, ”Climate change mitigation”, ”Iron and steel industry”, ”Cement industry”, ”Scenario” and ”Pathways”. Searched literatures were screened using the following criteria.

(1) The literature analyzes CO_2 or GHG emission reduction pathways based on the long-term targets set in the Paris Agreement.
(2) The literature reports CO_2 or GHG emissions after 2050 or longer for the steel or cement sector.
(3) The literature is a peer-reviewed and written in English.

From the screened literatures, we collected information on "direct CO2 or GHG emissions in 2020 and 2050", "model type", "target country or regions", "target sectors", "emission reduction technologies", and "representation of emission reduction technologies in the model".

Result

A total of 182 literatures were collected through the search using the keywords described above, and a total of 34 literatures were included through screening (Figure.1). The number of studies by year shows a sharp increase after 2022.

A total of 107 emission mitigation scenarios were reported in the 34 literatures. Of these, 34 scenarios were estimated using IAMs and 73 scenarios were estimated using a single-sector models. Noting the relationship between the types of models and the technologies considered in the models, the single-sector model considered a wide range of emission reduction measures, while the IAMs were more likely to consider fuel switching and CCUS (Figure.3).

Studies using sector models that estimated particularly high emission reduction rates considered a wide range of emission reduction technologies by combining modules that account for demand and waste supply by considering product stocks and flows[15),20)], or by using dynamic material flow analysis[31),32)].

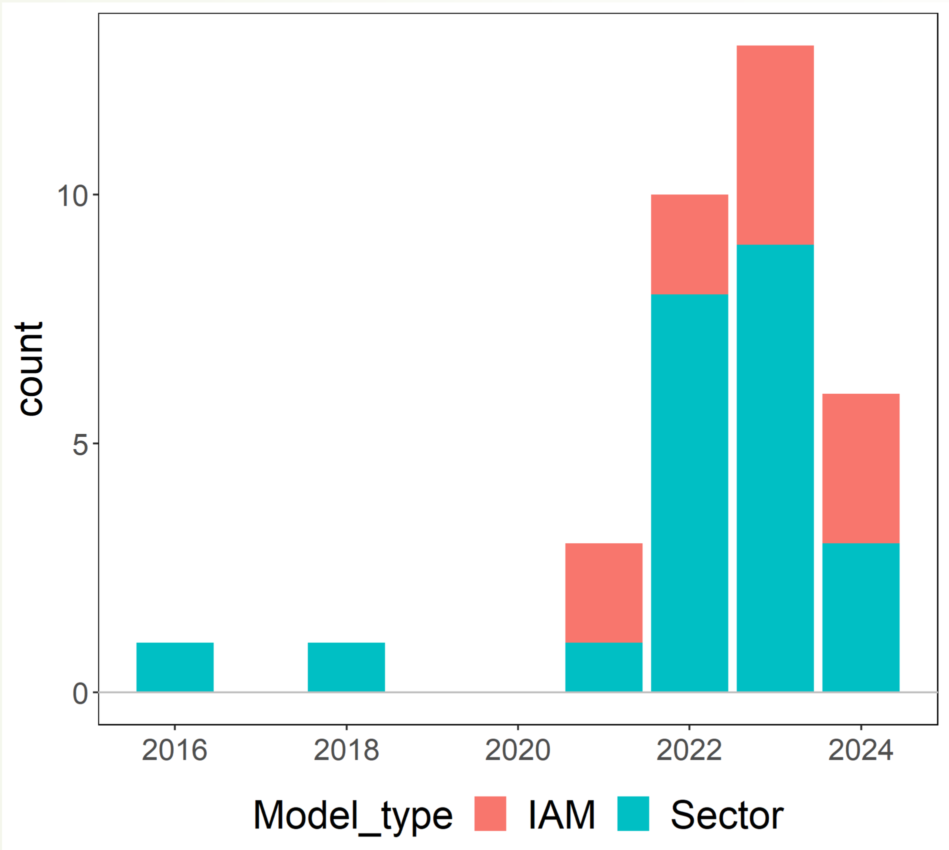

Figure1. Number of studies by year

Table1. Statistics on emission reduction rate in the reported literatures(%)

	Iron & steel		Cement	
Model	IAM	Sector	IAM	Sector
Ref.	2)-12)	13)-22)	10),23)	24)-35)
Median	66.2	78.8	63.6	75.8
Quantile	76.3	86.4	64.9	87.6
Max	93.0	100	66.1	104

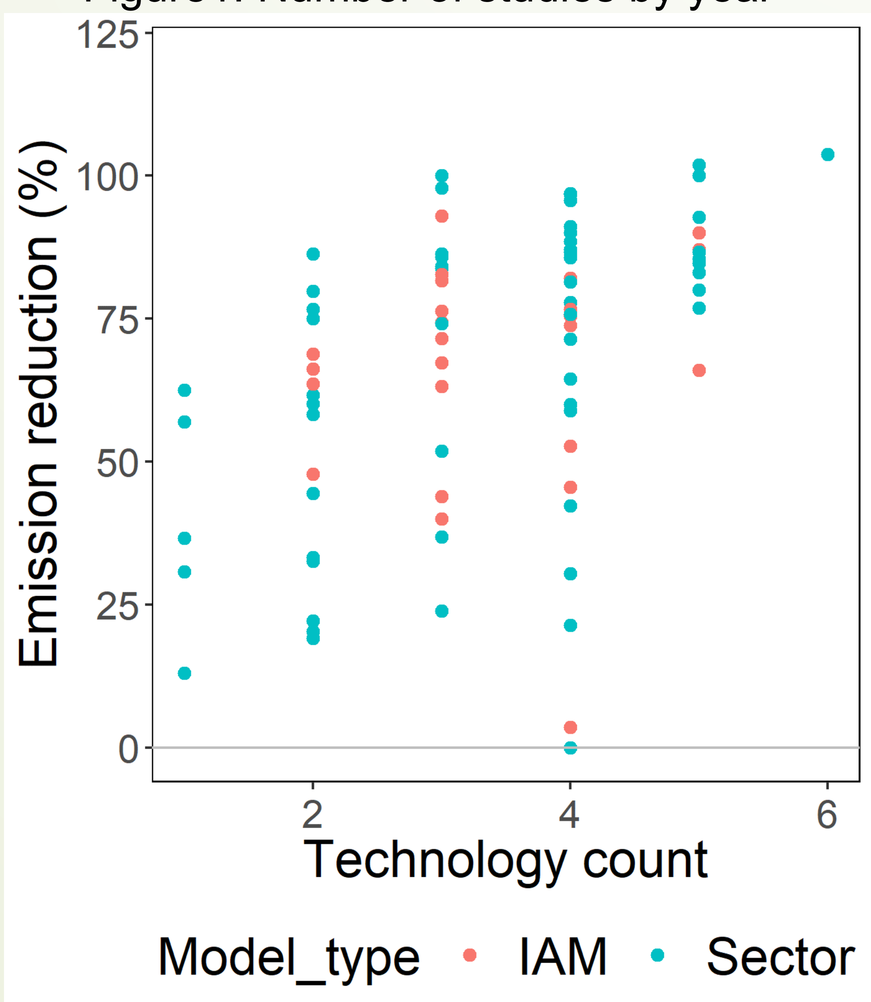

Figure2. Relationship between the number of technologies considered in the scenario and the reduction rate

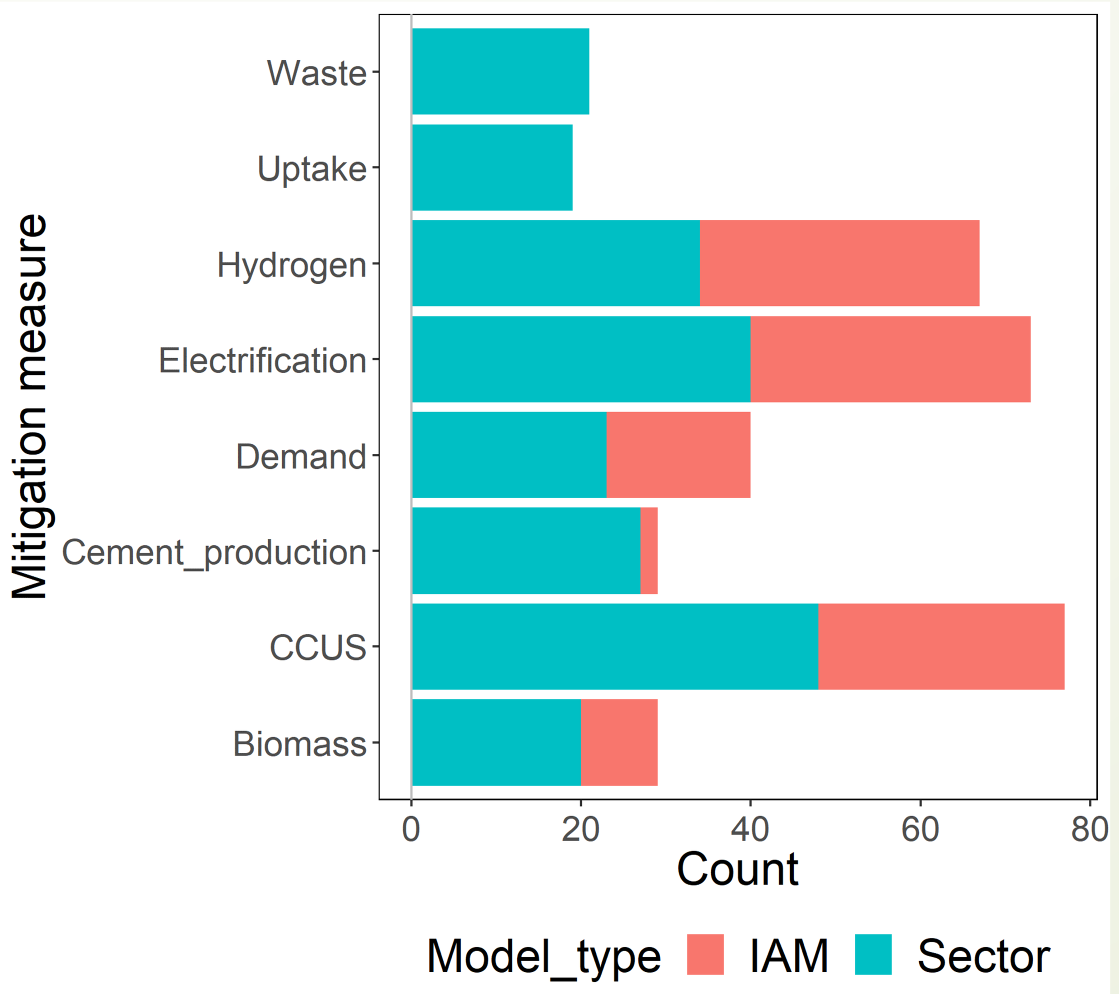

Figure3. Relationship between the type of model and the technology under consideration

Conclusion

This study collected and organized studies that estimated mitigation scenarios for the industrial sector. The literature review showed that single-sector models tended to consider more emission reduction technologies and estimate higher reduction rates compared to IAMs. When focusing on studies that estimated particularly high reduction rates, the estimates were made using sector models that consider material flows and stocks as well as inter-sectoral linkages.

IAM which integrates energy system model as a core model focus on energy supply and demand and do not adequately represent material stocks and flows and inter-sectoral linkages. CGE based IAM is expressed in monetary terms, which makes it difficult to capture the physical stock of materials. To represent emission reduction technologies in the industrial sector, IAMs are need to be linked with single-sector models.

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