Carbon Border Adjustment to avoid carbon leakage for Europe's chemical industry? A life-cycle based assessment

Hannah Minten[a],+492418098171, hannah.minten@ltt.rwth-aachen.de
Julian Hausweiler[a], +491733288564, julian.hausweiler@rwth-aachen.de
Benedict Probst[b,c], +41782235853, bprobst@ethz.ch
Christiane Reinert[a], +492418098179, christiane.reinert@ltt.rwth-aachen.de
Raoul Meys[a,d], +492418090477, raoul.meys@carbon-minds.de
André Bardow[e,f], : +41 44 632 94 60, abardow@ethz.ch

[a]Institute of Technical Thermodynamics, RWTH Aachen University
[b]Group for Sustainability and Technology, ETH Zurich
[c]Cambridge Centre for Environmental, Energy and Natural Resource Governance, University of Cambridge
[d]Carbon Minds GmbH
[e]Energy & Process Systems Engineering, Department of Mechanical and Process Engineering, ETH Zurich
[f]Institute for Energy and Climate Research (IEK-10), Forschungszentrum Jülich

Overview

Carbon leakage describes the shift of production to countries with less strict climate standards[1]. This shift may increase global carbon emissions. To prevent carbon leakage, a Carbon Border Adjustment Mechanism (CBAM) can be implemented as a "carbon tax" on imports[2]. The European Commission announced a CBAM on sectors at risk of carbon leakage, including the organic chemical and refinery sectors. However, the 2021 EU CBAM proposal explicitly excludes both refinery and organic chemical products due to technical limitations in determining the "embedded emissions" of products, i.e., the greenhouse gas (GHG) emissions from production[3].

Ideally, actual life-cycle GHG emissions should be calculated and taxed for individual imports[4,5]. The Life-Cycle Assessment (LCA) methodology, for instance, allows the holistic assessment of environmental impacts of a product along the entire life cycle, including GHG emissions[6,7]. However, the determination of life-cycle GHG emissions requires complete knowledge of the specific supply chain of each import. Thus, CBAM design faces a trade-off between the accuracy of calculated "embedded emissions" and the administrative feasibility of a given design[4,5]. In response, the literature proposes numerous CBAM designs with simplified approaches to calculate embedded emissions[8–12].

This study examines the effectiveness of different CBAM designs for the chemical industry, using the LCA methodology and novel LCA databases that provide supplier-specific GHG emission data[13]. We investigate CBAM designs proposed in the literature on the exemplary case of the major bulk chemical ethylene. We answer the question: To what extent do the proposed CBAM designs accurately price the embedded GHG emissions of a chemical product? Analyzing the design propositions, we derive conclusions to support effective CBAM design for the chemical industry from a life-cycle perspective.

Methods

Embedded emissions are calculated according to proposed CBAM designs. For this purpose, we employ supplier-specific data from the chemical industry and LCA databases. We further determine the actual life-cycle GHG emissions according to the LCA methodology. Comparing LCA results and embedded emissions, we investigate whether the CBAM designs accurately reflect differences in product GHG emissions.

To illustrate our findings, we present the case study of ethylene imports from China to the EU. We choose ethylene due to its importance to the chemical industry and its high trade volume.

Results

The life-cycle GHG emissions from ethylene production vary drastically with the production route and feedstock used. For instance, GHG emissions from ethylene production in China range from 1.5 to 12 kg CO_2-eq per kg of ethylene. China employs eight different process/feedstock combinations for ethylene production, only four of which are also used in the EU, namely steam cracking processes[13]. A contribution analysis reveals that the majority of GHG emissions in ethylene production result from the supply of raw materials for most routes. Steam cracking is an exception, since here direct process emissions significantly contribute to overall GHG emissions.

Due to difficulties in data collection, GHG emissions from raw material supply are neglected in all proposed CBAM designs. Instead, the CBAM designs focus on direct process emissions and energy-related emissions. Hence, the resulting embedded emissions deviate substantially from the actual life-cycle emissions for ethylene. Consequently, producers with lower life-cycle emissions might have to pay higher taxes than higher-emitting producers simply because the emissions are distributed differently in the supply chain.

This misalignment of the CBAM designs can be avoided by using average embedded emission values on a product or sector level. However, employing default values for embedded emission do not reflect actual life-cycle emissions. In result, foreign producers have no incentive to decrease emissions. Additionally, averages overcharge foreign

producers with lower-than-average emissions. Allowing producers to prove their superior performance solves the overcharging issue, albeit at the cost of higher administrative effort.
As the most produced platform chemical, ethylene is located upstream in the overall chemical industry supply chain. Still, its global supply chain already shows great variety, impacting the CBAM mechanisms. Since the supply chain is even more complex and challenging to track for downstream products, we expect that our findings on CBAM design hold widely for the chemical industry.
Overall, the chemical industry comprises a large variety of products with about 350 000 chemicals (or their mixtures) on the global market[14]. This diversity leads to a large variance in embedded emissions between products. We show that, even for a single chemical product, the embedded emissions vary drastically with the production process and the choice of feedstock and fuel. Moreover, complex supply chains in the chemical industry often make it practically impossible to identify the feedstock used. Processes in the refinery and chemical industry are also often multi-functional, i.e., produce more than one chemical at once[15]. In the case of multi-functionality, product-specific emissions cannot be measured. Instead, process emissions must be allocated to the products[7,15]. The additional complexities render the proper reflection of GHG emissions in CBAM design challenging.

Conclusions

The challenge in designing CBAM for the chemical industry is accurately calculating GHG emissions "embedded" in chemical products while keeping the administrative effort manageable. The case study on ethylene demonstrates that the amount of life-cycle emissions and their distribution along the supply chain depend on the specific process and feedstock used. However, none of the proposed CBAM designs incorporate raw material-related emissions into the calculation of embedded emissions. Our results show that, depending on the CBAM design, low-emitting producers might be charged for equal or higher emissions than high-emitting producers on imports into the EU.
A transparent global chemical supply chain would allow for accurate calculation of embedded emissions across the entire life-cycle. Our findings emphasize the need for enhanced transparency in supply chains to enable effective climate policies targeting the chemical sector.

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