Reply to Comment on ‘From the Paris Agreement to corporate climate commitments: evaluation of seven methods for setting “science-based” emission targets’

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Abstract
The Science Based Targets initiative has published a Comment to our study (Bjørn et al 2021 Environ. Res. Lett. 16 054019). We see the Comment as an important step towards addressing our study’s call for more systematic presentation of methods for setting science-based targets and increased transparency behind the initiative’s method recommendations. We also agree with some of the Comment’s points of criticism of our study and the related nuances introduced. Yet, we find other points to be inaccurate or misdirected. Here, we reply to the Comment by clarifying misunderstandings on our study’s aims, providing additional methodological details, and elaborating on our perspectives.

1. Introduction

Our reply is structured along the four issues presented in the Comment, after which we outline a broad reflection on the three assessment principles proposed in the Comment for evaluating science-based target (SBT) methods. Throughout our reply, we identify several questions that will require in-depth research. They are summarized in table 1.

Before embarking, we would like to stress two things. First, we find it very encouraging that the Science Based Targets initiative (SBTi) is mobilizing unprecedented commitments to reducing emissions from a large number of major companies (SBTi 2021a, 2022). Second, we have no interest in promoting certain SBT methods over others. Our main interest is to achieve greater transparency around methods and companies’ use of them, to ensure that SBTi’s reference to a scientific basis stands up to scrutiny. We believe that this will improve the long-term viability of the SBT concept and progress towards global emissions levels aligned with the Paris temperature goal.

2. Reply to: characterization of SBT methods

As an extension to our method characterization approach, SBTi suggests distinguishing between emissions allocation occurring in a scenario (‘scenario choice’), prior to the consideration of any company data, and emissions allocation defined by a method’s targets equation (‘formula allocation principles’). SBTi further suggests indicating whether a method uses a scenario that is global or resolved according to sectors and/or regions (‘granularity’). Accordingly, SBTi proposes a new way of presenting and comparing the characteristics of the seven SBT methods that captures this distinction (table 1 in the Comment).

We agree that such an explicit distinction is useful because allocation principles originating in target equations are inherent to an SBT method, while principles related to global scenarios may change with the adoption of a new global scenario. Another reason for making the distinction is that allocation of global emissions to regions or sectors through a scenario must be followed by allocation to individual
companies through a method’s target equation in a two-step process. On the other hand, when the adopted scenario has no regional or sectoral granularity, a method’s target equation directly allocates global emissions to the company-level. It may also be worth distinguishing between methods that are flexible with respect to granularity (the Center for Sustainable Organizations’ context-based carbon metric (CSO) has been applied both with a global scenario and a scenario for the Organisation for Economic Co-operation and Development (OECD) (CSO 2021)) from methods that are designed for a specific granularity (the sectoral decarbonization approach (SDA) requires scenarios with sectoral granularity (SBTi 2015)). We also agree with SBTi that distinguishing between emission allocation related to target equation, granularity and scenario choice clarifies that the target equations of the greenhouse gas emissions per unit of value added (GEVA), British Telecom–Carbon Stabilization Intensity (BT-CSI), Corporate Finance Approach to Climate-stabilizing Targets (C-FACT), and CSO methods reflect the same two allocation principles, namely grandfathering (termed legacy entitlement in the Comment) and economic contribution. However, this similarity does not mean that the target equations of those four methods are identical (see supplementary material of Bjørn et al 2021). Most notably, while GEVA, BT-CSO and C-FACT all generate exponential company-level emission pathways, the CSO method (like the SDA method) generates pathways that reflect the shape of the adopted global (or regional) emission pathway (see figure 3 in Bjørn et al 2021). This difference in method behavior has major implications for the emission imbalances of those four SBT methods (ibid), but this is not captured by SBTi’s typology of ‘allocation formula’ (first column in table 1 in the Comment) or its attempt to represent the four methods by a common target equation (supplementary text 1 in the Comment).

SBTi goes on to claim that we ‘incorrectly assume that regional differentiation is synonymous with the principle of responsibility-based emissions allocation (“or right to development or capabilities”’) and that we ‘incorrectly assume that sectoral differentiation is synonymous with cost optimization’. This is not correct. Nowhere in our study do we state that scenarios with regional or sectoral differentiation are always associated with one or more specific allocation principles. We will use this opportunity to clarify how we derived the scenario-related allocation principles in our study. The documentations of the four SBT methods applying regionally differentiated scenarios (BT-CSI, C-FACT, CSO and 3% solution) all refer to a differentiation between developed and developing countries and some of the documents use wording that associates with responsibility (‘luxury of emitting heavily ever since the industrial revolution’), right to development (‘development status’) and capacity (‘industrialized countries must take the lead’) (see table A1 of this Reply for details). As mentioned in our study, some method documentation lacks complete references to the specific global scenarios involved. Hence, we were not able to systematically access the underlying documentation of global scenarios to clarify the exact allocation principles involved. Nevertheless, we find it reasonable to assume that the scenarios involved in those four SBT methods reflect responsibility, right to development, or capacity (individually or in combination). This is not to say that all scenarios with regional granularity reflect those allocation principles (as SBTi’s separation of granularity and scenario choice correctly reflects). Indeed, factors such as population- and economic projections and potential for deployment of low-carbon technologies often play a strong role in differentiating regional emission pathways within scenarios generated by integrated assessment models (Riahi et al 2017). Considering the documentations of the two SBT methods applying sector differentiated scenarios (3% solution and SDA), there are extensive references to cost-saving, cost-minimization, and least-cost mitigation (see table A1 of this Reply for details). In the documentation of the SDA method (which was co-authored by two of the Comment’s authors), the first paragraph of the foreword includes the sentence: ‘this report presents least-cost pathways for companies in energy-intensive sectors to reduce emissions to levels

| Question                                                                 | Related section |
|-------------------------------------------------------------------------|-----------------|
| How to communicate normative aspects of emission scenario to companies and their stakeholders? | 2               |
| What are the merits of using a single (non-linear) scenario versus a linearized scenario envelope approach with SBT methods? | 3               |
| May the involvement of multiple allocation principles within a single SBT method lead to normative inconsistencies? | 4               |
| What combinations of SBT method and company characteristics allow an increase in companies’ emissions and under what conditions is this problematic? | 4               |
| What is the degree of support for the allocation principles involved in SBT methods by different stakeholders? | 4 and 5         |
| Are SBTi’s new principles to evaluate SBT methods appropriate and complete? | 6               |

Table 1. Summary of new research question emerging from this Reply.

Environ. Res. Lett. 17 (2022) 038001

A Bjørn et al
commensurate with a global 2 °C pathway’. We have no reason to doubt that the underlying scenarios, developed by the International Energy Agency (IEA), are ‘not fully cost optimized’, as stated in the Comment, but the SDA documentation certainly highlights the role of cost-optimization.

Having made its case for the complex relationship between global scenarios and allocation principles, SBTi then argues that scenarios are ‘challenging to summarize uniformly across methods and frequently updated by method developers’. We understand the concern of representing allocation principles (e.g. cost-optimization) as binary classifiers for scenarios generated by complex models that do not apply the principles fully or in the same way. Nevertheless, we find it important that SBTi (and developers of individual SBT methods) communicates the normative assumptions that are embedded in the adopted scenarios. Indicating only the level of granularity (global, regional or sectoral) will likely prevent companies and other stakeholders from fully understanding the value judgments and associated subjectivity embedded in a chosen scenario. Hence, we encourage SBTi to introduce information to the Comment’s table 1 about how the scenarios allocate global emissions to sectors or regions. Relatedly, we encourage more research on how to communicate normative aspects of scenarios to companies and their stakeholders. In addition to regional and sectoral emission allocations, normative scenario aspects include, amongst other things, the balance between supply-side and demand-side interventions (Mundaca et al 2019, Nelson and Allwood 2021), the probability of meeting the stated temperature goal, the role of negative emission technologies, and the associated risk of a temporary overshoot of the temperature goal (Smith 2021).

3. Reply to: the SBT method formula used for absolute contraction approach (ACA) does not match the SBTi’s application of ACA

We thank SBTi for clarifying that its use of the ACA method explicitly involves the period 2020–2035. This was not apparent to us before, in part because the 2020 version of the SBTi manual (SBTi 2020) encouraged companies to ‘develop long-term targets (e.g. up to 2050)’, in addition to targets with a shorter timeframe. We note that the SBTi still encourages such long-term targets, but has made it clearer that they are complementary to the mandatory 5–15 years targets (SBTi 2021b).

We also thank the SBTi for drawing a link between our emission imbalance analysis for the ACA method and its ‘foundations of science-based target setting’ document (SBTi 2019). We agree that our finding that the emission imbalance for ACA is highly dependent on the shape of the global emission pathway is consistent with the Comment’s cited text from that document. Note that the foundations document describes the construction of a scenario envelope, used by SBTi to determine ‘minimum annual linear reduction rates’ within the 2020–2035 period for the 1.5°C and well-below 2°C goals, respectively. It is worth pointing out that SBTi’s application of the ACA method is the only case that involves the creation of a scenario envelope and a linear representation of it. All other applications of SBT methods (that we know of) rely on a single emission scenario that is usually not linear. For example, the SDA method relies on a single non-linear sectoral emission scenario (for a given temperature goal) developed by the IEA (Krabbe et al 2015, SBTi 2019).

We therefore encourage the SBTi to explain why they deem the use of a single (non-linear) scenario appropriate in some cases and the linearized scenario envelope approach appropriate in others. Likewise, we invite the research community to assess the relative merits of these two approaches.

4. Reply to: allocating global emissions based on economic growth yields incoherent results

SBTi argues that the economic contribution allocation principle ‘seems inconsistent with the consensus in academic literature’ because it allows fast-growing sectors to reduce emissions slower than slow-growing sectors. We agree with the latter, but question the reference to an academic consensus. It is true that emission scenarios with sectoral resolution often assumes that the power sector will both decarbonize faster and grow at a higher rate than many other sectors (e.g. cement in the IEA scenario adopted by the SDA method (SBTi 2015)). From our understanding, this is largely a consequence of the application of a cost-optimization algorithm in the underlying models (e.g. the models consider emission reductions from replacing coal with solar power to be cheaper than emission reductions from increasing the energy efficiency of cement production). Hence, the inconsistency claimed by SBTi stems from a conflict between the economic contribution and cost-optimization principles. It is not our role to judge which principle is more appropriate or fair (we did not make any such judgment in our study). It may well be that cost-optimization enjoys more general support than economic contribution for allocating global emissions between economic sectors. However, we caution against equating the common use of a specific normative principle in the academic literature with a broad societal support for that principle (Dooley et al 2021). Accordingly, we encourage more research on the support of individual allocation.
principles by different stakeholders. Future research should also consider whether the reliance on multiple allocation principles within a single SBT method may lead to normative inconsistencies, as argued in the Comment (e.g. in the case of economic contribution and capacity).

SBTi then turns to emission allocation within a given sector and questions ‘why a company with slow economic growth would be required to reduce emissions faster than a company with high economic growth’. This is indeed a consequence of the economic contribution principle. If SBTi perceives this as problematic, then we question why it does not also question the physical production principle, adopted in the SDA method, on similar grounds. The physical production principle means that companies that have a relatively high growth in physical production will not need to reduce emissions as much as other companies. As such, when applied within sectors, the economic contribution and physical production principles can be seen as sub-principles of a higher-order principle that may be termed activity, since economic value added and physical production are both measures of activity. Therefore, the economic contribution and physical production principles may both, in theory, allow fast-growing companies to increase their emissions (rather than requiring them to reduce emissions). SBTi presents this as a unique problem for the CSO method, but both Krabbe et al (2015) (co-authored by one of the Comment’s authors) and our study (Bjørn et al 2021) contain examples of the SDA method allowing companies to increase emissions. Granted, both of these cases involve hypothetical companies and it may be that the CSO method more often allows emission increases than the SDA method in practice, insofar as companies can grow value added without growing physical production. On the other hand, some companies may be able to grow physical production without growing value added, e.g. through increased automatization that leads to less labor per unit of production. Regardless, we question SBTi’s claim that a ‘typical’ large company may grow its value added at around 9% per year and, consequently, be allowed a substantial emission increase, according to the application of the CSO method in the Comment. The sum of the value added of companies within a country is roughly equal to its gross domestic product (GDP) (Randers 2012, BEA 2015). Hence, companies’ growth in value added should be reflected by GDP growth. Considering historical GDP growth rates (World Bank 2020), a company growing its value added by 9% per year does not appear ‘typical’. Note also that the data source referred to in the Comment (Damodaran 2021) relates to growth in revenue and not in value added. Accordingly, we encourage research that clarifies what combinations of SBT methods and company characteristics that allow an increase in companies’ emissions and under what conditions this may result in a global emission imbalance (e.g. if company-level growth projections are systematically higher than the GDP growth projection of global scenarios).

5. Reply to: Incomplete evaluation of SBT methods

SBTi argues that our study is framed as a broad evaluation, while focusing on emission imbalances, and that readers may therefore interpret its results as a ‘reflection of overall method integrity’. We concede that our study’s title may give some readers the wrong impression that it contains a rating of methods based on a comprehensive evaluation. However, we believe that our study’s text makes it clear that it compares the characteristics of SBT methods with special attention to the issue of emission imbalance. This focus on emission imbalance was not accidental, but motivated by SBTi’s references to the concept, e.g.: ‘unlike the absolute contraction and SDA methods, GEVA only maintains a global emissions budget to the extent that the growth in value added of individual companies is equal to or smaller than the underlying economic projection’ (SBTi 2020) and ‘The Science Based Targets initiative recommends companies use either the sectoral decarbonization approach or the absolute emissions contraction method to set their scope 1 and 2 targets as these methods ensure that global emissions are reduced in absolute terms in the long term. They are the most robust methods to ensure the 2 °C carbon budget is conserved’ (SBTi 2018) (the text from the latter quotation is no longer on the SBTi website.). Statements like these clearly suggested that emission imbalance played a role in SBTi’s method recommendations, but SBTi did not provide any documentation. Hence, we decided to include a systematic emission imbalance analysis as part of our study. Note that our study does not propose that emission imbalance should be the only factor considered when recommending one or more methods over others. For example, we listed a series of other potential factors in section 4.3.2 (Bjørn et al 2021), ending with the statement: ‘given these pros and cons of individual methods, the SBTi should be transparent about the reasons underlying its method recommendations’.

We would also like to clarify that our study’s identification of allocation principles in SBT methods was not done for us to evaluate their ‘appropriateness’ or fairness. Instead, it was done for the scientific community, companies and their stakeholders to understand the normative implications of individual SBT methods and make comparisons across methods. As already mentioned (section 4 of this Reply), we support further research on the perspectives of different stakeholders on the range of allocation principles.
involved. Such research may, in turn, inform method guidelines for companies.

6. A brief reflection on SBTi’s principles to evaluate SBT methods

Our study was partly motivated by a lack of explicit principles behind SBTi’s method recommendations. As such, we welcome the idea of developing a set of principles for evaluating SBT methods and appreciate the initial set of principles presented in the Comment and the high-level assessment of SBT methods against them. In fact, our assessment of emission imbalance aligns with the third principle proposed in the Comment ('relevant emissions budgets are conserved'). However, we believe a more rigorous approach is needed to develop a comprehensive set of evaluation principles and evaluate the SBT methods against these principles than what is provided in the Comment. Below, we outline a broad reflection that may be useful in that regard.

- What values underlie the proposed principles for method evaluation and are these broadly shared by SBTi’s stakeholders (Pulkkinen et al 2022)? Is there a need for a consultation process?
- Should a method evaluation process aim to recommend a pre-determined number of methods (if so, what is an appropriate number for companies to choose between?) or should all methods that fulfill certain requirements be recommended?
- Should evaluation principles be universal or tailored to the current basket of SBT methods? (SBTi’s proposed principles appear to make several implicit references to the SDA method through specific criteria for ‘heavy-emitting sectors’).
- Should an SBT method be broadly applicable or specialized to certain company types? (For example, the SDA method is restricted to companies in ‘homogenous sectors’, whereas the ACA method is broadly applicable).

7. Conclusion and outlook

We appreciate SBTi’s Comment to our study, which addresses some of the issues raised in it (i.e. the need for increased transparency), while giving rise to new questions (e.g. table 1 of this Reply). More broadly, we fully agree that a ‘productive dialogue between the academic community and the business climate action community’ and other key stakeholders is needed and we hope that this exchange can catalyze additional productive dialogue. We also agree that there is a great need for research on SBTs beyond the method focus of this exchange. In that sense, we find the recent publications of several studies on SBTs encouraging (for example, Giesekam et al 2021, Freiberg et al 2021). We hope that this is a sign that academic attention to SBTs will increase proportionally to their uptake, helping to ensure that SBTs set by companies support achievement of the temperature goal established by the Paris Agreement.

Data availability statement

Any data that support the findings of this study are included within the article.

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Appendix

Table A1. Excerpts of text from the documentation of SBT methods that relate to scenario-based allocation principles (intrinsic). GHG: Greenhouse gas.

| SBT method | Relevant text (emphasis added) | Reference to document |
|------------|--------------------------------|-----------------------|
| BT-CSI     | 'In line with the principles of contraction and convergence, developed countries are expected to aim for an emissions peak between 2012 and 2015, with 30% cuts by 2020 and at least 80% cuts by 2050. Developing countries meanwhile will essentially maintain a trajectory of rising emissions to 2020, peaking at around 80% above current levels, with cuts of 20% against 1990 levels by 2050.' | Tuppen (2008) |
| C-FACT    | Acknowledging that emissions are closely correlated with economic growth, that industrialized countries represent the vast majority of emissions per capita and have had the luxury of emitting heavily ever since the industrial revolution, climate scientists and policy experts recommend that industrialized countries must take the lead in bending this upward emissions curve. Specifically, they recommend GHG reductions as follows:  
• Eighty five percent absolute GHG reduction by industrialized countries by 2050.  
• Fifty percent absolute GHG reduction by developing countries by 2050. | Stewart and Deodhar (2009) |
| CSO (2015 version) | Does your metric assign different degrees of responsibility to mitigate emissions to emitters in different parts of the world based on their development status? Or does it treat all emitters alike? Most of the mitigation scenarios we use do, in fact, differentiate between emissions in the developed versus still-developing parts of the world, and thereby assign higher mitigation burdens to emitters in the developed world. | McElroy (2015) |
| The 3% solution | According to the IPCC, to meet this goal developed countries need to reduce GHG emissions by 25%–40% below 1990 levels by 2020, and 80%–95% below 1990 levels by 2050. Reductions referenced in this report are drawn from the McKinsey US GHG cost curve and represent those that have a marginal abatement cost by 2020 of US$35 per tonne or less. | WWF/CDP (2013) |
| SDA       | The SDA is differentiated from other existing methods by virtue of its subsector-level approach and global least-cost mitigation perspective. SDA results and assumptions are based on mitigation potential and cost data from the IEA’s TIMES model 2 °C scenario, which identifies the least-cost technology mix available to meet final demand for industry, transport, and buildings services. IEA’s 2DS provides a cost-competitive mitigation pathway to achieve the 2 °C target, while acknowledging differences in activity growth, mitigation potentials, and technological options for each sector. | SBTi (2015) |

* Based on the cost-minimization criteria.
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