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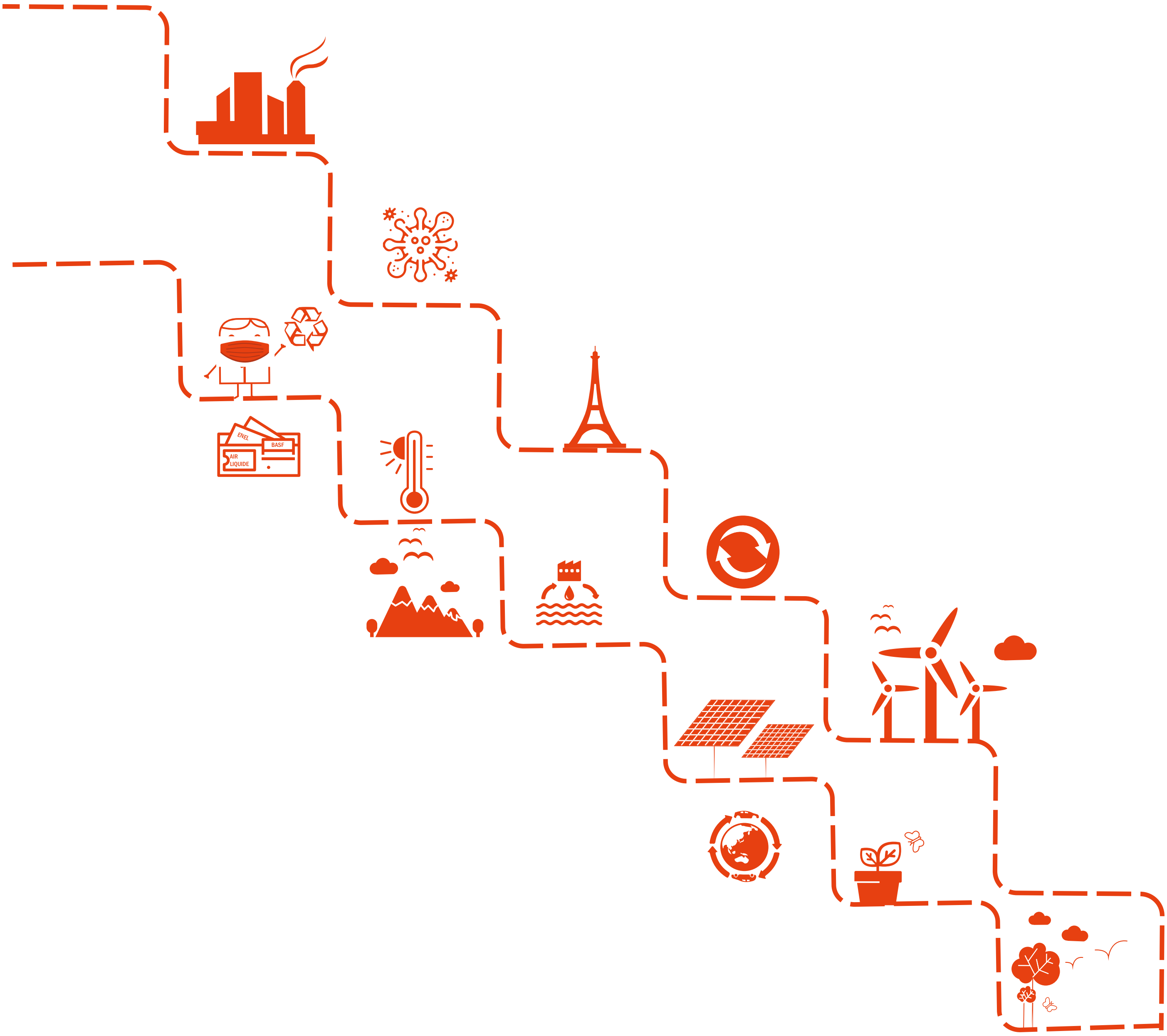
IMPLIED TEMPERATURE RISE OF EQUITY PORTFOLIOS: A SENSITIVITY ANALYSIS FRAMEWORK



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ABSTRACT

Faced with the multiplication of methods for calculating a company or financial portfolio implied temperature rise (ITR) and the divergence of their results, this report introduces a framework for carrying out sensitivity analyses of their design choices. We develop a generic ITR model with fifteen parameters based on the review of existing literature and methodologies carried out in the “Alignment Cookbook 2” report (ILB, 2024). These parameters are grouped into three groups corresponding to three methodological steps in the construction of an ITR: (i) the definition of a decarbonization benchmark for the companies, (ii) the projection of the expected greenhouse gas trajectory of companies, and (iii) the calculation of the ITR from the benchmark and the projection using an overshoot[1]. The model makes it possible to conduct a sensitivity analysis for each ITR parameter.

We first focus on how different carbon budget allocations impact decarbonization benchmarks. We show that for companies whose starting intensity is higher (lower) than that of the sector, the “reduction” approach is the least (most) restrictive in terms of carbon budget, followed by the “convergence” and the “fair share” approach[2].

We then analyse among eleven of the fifteen factors those who have the most impact on the overshoot and ITR of three companies in the steel sector. We first show that for a model based on carbon budgets, it is preferable to compare overshoot rather than ITR due to the uncertainties surrounding the transient climate response to cumulative CO_2 emissions and the horizon considered. We then show that the parameters used to normalize emissions (production, revenue or gross profit), to project carbon intensity (constant, historical or based on company emission reduction targets), and the time horizon considered have the greatest impact on the overshoot of these three companies.

While these initial results should be treated with caution as they are the result of specific methodological choices and based on one sector and three companies, they suggest that research should pay a special attention to these parameters to reduce discrepancies between results. This framework also paves the way for future work on portfolio-level and financial entity-level aggregation options that will be explored as part of the CAPA project.

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[1] Defined as the ratio between the projected emissions and the benchmark.

[2] In the “reduction” approach, the intensity of the company must reduce at the same rate as that of its sector. In the “convergence” approach, the intensity of the company must converge with the intensity value of the sector on a given horizon. Finally, on the “fair share” approach, the absolute carbon budget for each year is proportional to the company’s market share.

INTRODUCTION

While it is clear that financial institutions have played a major role in causing climate change and must now contribute to its mitigation, there is no consensus on the specific tools to be used to measure their alignment to climate scenarios and contribution to climate change mitigation (ILB, 2024). Unlike other economic sectors, the effects of finance are essentially indirect - through financed entities - and therefore require more complex modelling to measure them.

To date, there are multiple frameworks, methodologies and tools to support financial institutions in their efforts to mitigate climate change. Based on an exhaustive review and analysis, ILB (2024) proposes to classify them into three categories: financial institutions' transition plan alignment assessment, asset/ portfolio-level target-setting, and asset/ portfolio-level alignment assessment3. In this report, we focus on the portfolio alignment assessment methodologies *"that aim to assess the "alignment", or "compatibility" or "consistency" of financial assets and/or portfolios with (a) given pathway(s) that limits global temperature rise under a specific level with a certain probability"* (ILB, 2024). More specifically, we focus on "*emissions-alignment methodologies*[4]" that lead to an implied temperature rise (ITR) metric – *i.e.* the global increase in average temperature compared to the pre-industrial era if the economy followed a trajectory like that of the company/portfolio.

There is an increasing number of methodologies available on the market for calculating a portfolio's ITR (ILB, 2024). ILB (2020) identified the methodological blocks common to these tools, but highlighted significant divergences in results, both at financial-asset and portfolio levels. Since this first report, several institutions have carried out comparative analyses of ITR methodologies leading to an identification of key design choices and first recommendations on of recommended options (FOEN, 2022; GFANZ, 2022c; OECD, 2022; PAT, 2020, 2021). Haalebos and Fouret (2022) and de Franco *et al.* (2023) have begun to explore the deviations generated by some of these parameters – greenhouse gas emissions scope, emissions projection, aggregation) and have shown that different options on these design choices can lead to deviations of more than 1°C in the ITR of companies and portfolios.

This report aims to contribute to this work by proposing a framework to conduct sensitivity analysis of the impact of different options for fifteen design choices on the ITR. To this end, we propose a generic ITR model based on existing literature and the specific analysis of 13 emissions-alignment methodologies for corporate assets (see ILB, 2024, for more details). The model architecture follows the three methodological steps conceptualized by ILB (2020) and PAT (2021) - construction of a decarbonization benchmark at company level, projection of the company emissions, and calculation of an ITR from an overshoot - and proposes fifteen parameters related to these steps for which different options are possible. The model thus makes it possible to isolate the impact of each parameter (design choice), all other things being equal. The model is specific for the analysis of equity portfolios, but most of the design choices analysed are common to methodologies applicable to other asset classes.

First, we discuss the implications of different allocation options to build the decarbonization benchmark of a company. This theoretical exercise is based on Krabbe et al. (2015) who introduced the "convergence" allocation and enables us to compare this first allocation option with the "reduction[5]" and "fair share" approaches. We show that, for companies whose starting intensity is higher than that of the sector, the reduction approach is the least restrictive, while the convergence approach is more restrictive but takes into account their initial intensity level. Finally, the fair share approach is the most restrictive for highly intensive companies, as it requires a significant reduction in carbon intensity from the reference year onwards. Naturally, the opposite is true for companies whose carbon intensity is below the sector average.

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[3] See ILB (2024) for an analysis of the links between these methodologies in the context of a growing interest in transition finance.

[4] ILB (2024) distinguishes three types of portfolio alignment assessment methodologies: emissions alignment, activity alignment and transition-plan alignment methodologies.

[5] Also called "contraction".

Once the mechanisms of these different allocation approaches have been discussed, we propose an illustration of a sensitivity analysis on three real companies from the steel sector. We suggest that, for an emissions-alignment model based on carbon budgets, it is preferable to analyse overshoot rather than ITR deviations. First, the uncertainties surrounding the transient climate response to cumulative CO_2 emissions (TCRE) used to convert a carbon budget to an ITR lead to significant deviations in ITR for the same overshoot. Second, when considering horizons limited to 2050, overshoot will generally be limited to 100%, which “only” corresponds to an ITR of 1.8°C when using a transient climate response to cumulative CO2 emissions method[6]. This might therefore not be representative of a company’s real alignment.

The overshoot of the three companies varies between 57% (ITR of 1.66°C) and 102% (ITR of 1.78°C) in the reference configuration of our model. The denominator used to normalize emissions has the greatest impact with an average overshoot deviation of 87% when moving from production to revenue or gross profit. Consistent with Haalebos and Fouret (2022), intensity projection has also an important impact on overshoot deviation when moving from constant intensity to historical trend or taking emission reduction targets of companies into account (average deviation of 77%). Finally, reducing time horizon from 2050 to 2030 leads to an overshoot deviation of 61% in average. On the other hand, the choice of scope generates lower overshoot deviation than the results presented by Haalebos and Fouret (2022) (15% in average), but this can be explained by the fact that the automotive sector studied by Haalebos and Fouret (2022) is more sensitive to scope 3 than the steel sector.

The scope and robustness of these initial results are limited by the fact that they are specific to the steel sector and do not incorporate aggregation parameters at portfolio level. They do, however, provide a better understanding of the mechanisms of each parameter and suggest that future research should pay special attention to certain design choices – denominator, intensity projection, time horizon - to reduce discrepancies between methodologies. This framework, designed to be systematic and reproducible also paves the way for future research on portfolio-level and entity-level aggregation parameters as part of the CAPA project.

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[6] When considering a 1.5°C scenario as reference.

A REVIEW OF EXISTING LITERATURE ON IMPLIED TEMPERATURE RISE

In this section, we present how our sensitivity analysis framework fits into existing frameworks to analyse emissions-alignment methodologies with a focus on methodologies leading to ITR metrics (1.1). We then summarize the existing results regarding deviations in ITR between methodologies for similar companies or portfolios (1.2).

1.1 Frameworks to analyse emission-alignment methodologies

Our sensitivity analysis framework is built on existing qualitative analysis frameworks developed by ILB (2020), PAT (2020, 2021) and ILB (2024).

ILB (2020) identified four steps - specific to corporate financial assets - to build ITR: (i) measuring the climate performance at the portfolio level, (ii) choosing one or several scenarios, (iii) converting macro emissions trajectories from these scenarios to portfolio trajectories, and (iv) comparing the results of first and third steps[7]. PAT (2020) builds on this initial segmentation to define three broader methodological steps – (i) translating carbon budgets into benchmarks, (ii) assessing counterparty-alignment, and (iii) assessing portfolio level alignment – and nine design choices ("*key judgements*") within these steps. While PAT (2021) already offered some recommendations for some of these choices[8], GFANZ (2022b) has proposed different options to be tested in order to measure the impact of each design choice. Finally, ILB (2024) has introduced the concept of "*systemically important design choices*" to designate choices that are likely to be relevant from a consolidated alignment perspective because they lead to large deviations in the alignment assessment metric (e.g. ITR) or because they matter from a scientific robustness perspective. The authors identify three systemically important choices: the scope and coverage of the assessment (both in terms of financial asset classes, sectors, greenhouse gases and their scope), the underlying scenario(s) and the downscaling of pathways from global to economic entities level, and the aggregation approach.

The construction of our model and its parameters is based on this work in many respects. First, regarding the type of decarbonization benchmark (PAT first design choice), our model focuses on single-scenario benchmark approach (as opposed to the warming-function approach[9]) as this is the approach recommended by PAT (2021) and GFANZ (2022c): *"practitioners should consider using a single-scenario benchmark approach because it is simpler to implement and its assumptions are easier to understand"* (p.36). In addition, our fifteen parameters have been defined so as to reproduce as closely as possible the options defined by GFANZ (2022b). Finally, we added a number of parameters we felt were important, particularly in view of the systematically important design choices identified by ILB (2024) (Exhibit 1).

1.2 Quantitative analyses

The aim of our sensitivity analysis framework is to measure the impact of different options for each of the design choices identified by the qualitative frameworks presented above. To our knowledge, few studies have quantified the divergences generated by these choices, but we can already draw some useful observations.

Whether at portfolio or company level, the alignment scores provided by different methodology providers diverge significantly, generally by more than 1 °C[10]. For example, ILB (2020) show divergences between eleven methodologies by applying them on two indices, the Euronext Low-Carbon 100[11] and the SBF 120. For 2019, the resulting ITR vary between 1.5 °C and 3 °C for the Euronext Low-Carbon 100 and between 2.5 °C and 3.5 °C for the SBF 120. When looking at correlation between ITR at company-level, the authors conclude that "*there is little, or even negative correlation between most of the methods[12]*" (p.82). However, these deviations in ITR may stem from differences in *several* design choices (e.g. different scenarios and different allocation methods). Some studies have therefore sought to isolate the specific effect of some of these design choices.

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[7] These steps were further divided into fifteen methodological choices.

[8] See the part B of their report "What makes a good portfolio alignment tool?".

[9] PAT (2020) distinguish between two ways of creating a decarbonization benchmark from a reference scenario(s). The first -single scenario benchmark- consists in extracting emissions trajectories for each industry and company from a single scenario. The second - warming function – consists in constructing a statistical function describing the correlation between one or more emission (or emission intensity) variables and a given temperature rise under several scenarios.

[10] While at first glance this deviation may not seem very important, we shall see later that it is when we convert it in terms of carbon budget overshoot.

[11] According to Euronext, "*[t]he Low Carbon 100 Europe® PAB is an index which reflects the performance of companies in the Euronext Europe 500 index that have the relative best climate score and the highest Free Float Market capitalisation.*" Source: https://live.euronext.com/fr/product/indices/QS0011131735-XAMS/market-information

[12] Despite the divergence in results, most companies don't seem to be aligned. Out of a sample of 25 companies from emissions-intensive sectors (airlines, autos, shipping, steel, chemicals, cement, aluminium, power utilities) and five alignment assessment methodologies, OECD (2022) shows that there is at least one methodology for which every company is considered non-aligned, whether in 2030 or 2050.

First, the design choice of greenhouse gas emissions *scope* alone can vary the temperature of a company by more than 1.8°C. Haalebos and Fouret (2022) analyse the deviations for three companies of the Automotive sector - which is particularly sensitive to scope 3 - and show that the resulting ITR can vary from 2.1°C to 3.9°C when moving from Scope 1+2 to Scope 1+2+3 (using a fair share approach).

Second, the design choice of greenhouse gas emissions *projection* alone can vary the temperature of a company and a portfolio by more than 1°C. In addition to different scopes, Haalebos and Fouret (2022) introduce a probabilistic approach to projecting GHG emissions to "*better reflects plausible future emissions reductions for individual companies*". More specifically, they project the first five years using the historical absolute emissions growth rate and then derive a range of possible emissions from two scenarios. This first uncertainty lead to score variations about 0.5°C and 1°C for three companies of the Automotive sector. The authors also consider the deviation at portfolio level when taking into account the emission company targets: they show that the resulting ITR vary between 2.1-2.5°C (with targets) and 3.1-3.7°C (without targets).

Finally, the design choice of aggregation alone can vary the temperature of a portfolio by more than 1°C. Based on the different options of aggregation proposed by CDP and WWF (2020), de Franco et al. (2023) show how the aggregation method impacts a portfolio's ITR. More specifically, they compare the weighted-average temperature (based on the financial weight of each financial asset in the portfolio) with carbon-weighted temperature[13] (based on the emissions of each financial asset in the portfolio). They show that under carbon weighted temperature, the contribution of a few sectors - energy, utilities, materials – becomes very important and tend to increase the portfolio ITR: the MSCI World Index ITR move from 2.07°C to 3.16°C.

These initial studies already show that divergences, whether measured at the level of financial assets or portfolios, can reach more than 1°C, and that the design choices of scope, type of projection and aggregation alone can generate such level of deviation. The aim of our sensitivity framework presented in the next section is to confirm these results and extend them to other parameters, in particular to the one identified by GFANZ (2022b) and ILB (2024).

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[13] Temperature scores are from Institutional Shareholder Services (ISS).

Exhibit 1: ITR methodological steps, design choices, and model parameters

ILB (2020) Methodological choice	PAT (2020) Methodological step	PAT (2020, 2021) Design choice	GFANZ (2022b) Quantitative study potential design [options]	Sensitivity analysis model parameter [options]
How to derive the micro-level benchmark?	Step 1: Translating scenario-based carbon budgets into benchmarks	1. What type of benchmark should be built?	Single-scenario benchmark Construction approaches [reduction, convergence, fair share]	*Allocation* [reduction, convergence, fair share]
How to choose one or several scenarios and associated trajectories?		2. How should benchmark scenarios be selected?		
How to derive the micro-level benchmark? How to express the micro-level benchmark?		3. Should absolute emissions, production capacity, or emissions intensity units be used?	Metric units [absolute, physical, economic]	*Sector treatment* [True/False] *Denominator* [production, revenue, gross profit, no denominator (absolute)]
Scope 3 or not scope 3? What metric may be used to measure climate performance?	Step 2: Assessing counterparty-level alignment	4. What scope of emissions should be included?	Scope inclusion approaches [1, 12, 123]	*Greenhouse gas emissions scope* [1, 12, 123, relevant]
How to forecast future climate performance?			Scope 3 emission types [TBD]	
Measuring the speed or the spread?		5. How should emissions baselines be quantified?		*Company growth treatment* [inorganic growth, organic growth, neutral]
		6. How should forward-looking emissions be estimated?	Emissions forecasting approaches [using historical emissions, using transition plan targets, using a combination of backward- and forward-looking info]	Market-share projection [historical trend, constant] *Intensity projection* [historical trend, constant, climate targets]
			Qualitative assessment approaches [TBD]	
		7. How should alignment be measured?	Time horizons [2030, 2035, 2040, 2045, 2050]	*Reference year* [2015-2021] *Horizon* [reference year – 2050]
How to express the results of temperature alignment assessments?	Step 3: Assessing portfolio-level alignment	8. How should alignment be expressed as a metric?	Metrics [ITR using TCRE, ITR using multiple benchmark interpolation, % misalignment, binary alignment]	*ITR method* [TCRE, model] *TCRE value*
How to aggregate and weight the results at portfolio-level?		9. How should counterparty-level scores be aggregated?		*ITR portfolio calculation* [Average, Sum] *ITR portfolio aggregation* [Weight, Total] *ITR time management* [Budget, Pathway]

MODEL AND DATA

The model calculates an ITR for a given portfolio based on company-level data, following three methodological steps identified by PAT (2020):

1. *Decarbonization benchmark*: the model defines, for each company in the portfolio, a benchmark, i.e. an emissions trajectory compatible with the scenario given for a company. Depending on the allocation option, this benchmark can be expressed in absolute emissions $(BE_{i,t,(ref \leq t \leq horizon)})$ or intensity $(BEI_{i,t,(ref \leq t \leq horizon)})$, with corresponding the reference year of the analysis.
2. *Projection of emissions*: The model projects the company's emissions trajectory between the reference date and the horizon $(TA_{i,t,(ref \leq t \leq horizon)})$.
3. *Overshoot and ITR aggregation*: the model assesses the company/portfolio alignment by computing a company overshoot (O_i) or a portfolio overshoot (O_p) based on the benchmarks and trajectories of the companies whose financial assets are held in the portfolio. This overshoot can be converted into an ITR (ITR_i, ITR_p).

2.1 Inputs: company characteristics and scenario

The inputs of the model are a list of companies, for which several characteristics are available, as well as a reference scenario associated with an average increase in temperature.

Each company within the portfolio belong to sector[14] - the choice of sectors being consistent with the Science-based Target initiative sector classification[15], the Transition Pathway Initiative classification[16], and the GFANZ (2022c) recommendations (see Exhibit 2). We consider as inputs the historical values of the following company characteristics: weight in portfolio w_{it}, market capitalization mkt_cap_{it}, revenue rev_{it}, gross profit $gross\_prof_{it}$, production $prod_{it}$, greenhouse gas emissions scope 1 $E1_{it}$, scope 2 $E2_{it}$ and scope 3 $E3_{it}$, and emission reduction target[17] $target_{it}$.

In section 3, we illustrate the model with three steel companies, using historical data from 2014 to 2021. All financial data were retrieved from Refinitiv, while carbon emissions were retrieved from annual reports[18]. Production data are derived from production intensity, from the Transition Pathway Initiative carbon performance database.

Exhibit 2: Model sectors

Sector	SBT*	TPI**	GFANZ (2022c)	Model production unit	Abb.	Relevant scope***
Oil & Gas		x	x	Barrel of oil equivalent	Boe	1+2+3
Power	x	x	x	Megawatt-hour	Mwh	1
Airlines	x	x	x	Thousand passenger-kilometres	mpkm	1
Automotive	x	x	x	Thousand passenger-kilometres	mkm	3
Steel	x	x	x	Tons	t	1+2
Cement	x	x		Tons	t	1
Other	x	x		Millions of US dollars	MUSD	1+2

*Science-based Target Initiative, ** Transition Pathway Initiative, *** The relevant scope is defined according to the Transition Pathway Initiative carbon performance methodology for each sector.

Scenario data includes, for each sector : revenue rev_{st} , gross profit (equivalent to the GDP) $gross\_prof_{st}$, production $prod_{st}$, and greenhouse gas emissions scope 1 $E1_{st}$, scope 2 $E2_{st}$, and scope 3 $E3_{st}$. Scenario selection is a design choice that can produce divergence between methodology results. In the current version, we however only consider one scenario due to due to the complexity of transforming scenario data. In order to test all the model's parameters, we need all the scenario data presented above, for each sector. However, most of the existing scenarios do not provide all of them.

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[14] We consider that companies have only activities related to one sector.

[15] Available at: https://sciencebasedtargets.org/sectors (visited on 22 April 2024).

[16] Available at: https://www.transitionpathwayinitiative.org/sectors (visited on 22 April 2024).

[17] In the current version of the model, we only consider whether a company has, or not, emission reduction targets.

[18] When the data was not found in the reports, data from Refinitiv or last available data have been used.

For example, scope 1, 2 and 3 are generally not provided for *each* sector. Similarly, revenue or gross profit by sector are not always provided. We therefore have to estimate the missing variables. For example, for the steel sector, we used estimated sector scope 2 and 3 emissions on the basis of the scenario scope 1 emissions and the median of company scope 2/1 and scope 3/1 distributions (details on calculation of missing variables are provided in Appendix). We have therefore chosen to focus on one scenario for this study, but the framework makes it possible to replace it by others in the future. The scenario chosen is the 2023 World Energy Outlook (WEO 2023 thereafter) free dataset, that includes world aggregated data for three scenarios (STEPS, APS, NZE). We use the Net-Zero Emissions by 2050 (NZE) scenario as a reference[19].

2.2 Defining a company decarbonization benchmark

The model defines the decarbonization benchmark based on parameters related to the emission metric (scope, denominator, and sector treatment parameters), the allocation approach (allocation parameter), and the time frame (reference date, and horizon parameters).

The scope parameters define which emissions from the value chain are considered in the construction of the benchmark, both for the company and the scenario emissions. The model can simulate four options: direct emissions only (scope 1), direct emissions and indirect emissions from energy consumption (scope 1+2), direct and indirect emissions from energy consumption, production and product use (scope 1+2+3), and the scope considered for each sector as relevant by the Transition Pathway Initiative (relevant) (Exhibit 2).

$$E = E1(+E2)(+E3)$$

Once the perimeter has been chosen, the model can use the absolute emissions to build the benchmark[20] or take into account the company size by dividing them by a financial or physical characteristic d, leading to an intensity metric EI. Four denominator options are available in the model: no denominator (absolute), normalization by revenue, by gross profit[21] or by production.

$$EI = \frac{E}{d}$$

Now that the emissions metric has been defined in terms of scope and eventually intensity, the allocation parameter defines the distribution of the decarbonization effort between companies by allocating to them the global carbon budget of the scenario. More than a technical choice, this is a political, even ethical choice that produces different incentives for companies. The model can simulate three options: the reduction, convergence and fair share allocations. To define and illustrate the impact of each option, we consider six hypothetical companies as defined by Krabbe et al. (2015). Of these six companies, three have an intensity higher than the sector average, while the other three have a lower intensity. Within each group, one company has a constant market share, while another sees its market share grow by 1.5% per year and the last one sees its market share decline by 1.5% per year (Exhibit 3).

The third parameter related to the emission metric is the sector treatment. With no sector treatment, all companies must follow the same decarbonization benchmark[22], whereas with sector treatment, specific benchmarks are defined for the following sectors: Oil & Gas, Power, Aviation, Steel, Cement, Automotive and Others[23].

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[19] Original dataset available at https://www.iea.org/data-and-statistics/data-product/world-energy-outlook-2023-free-dataset-2)

[20] In this case, the allocation is bound to reduction.

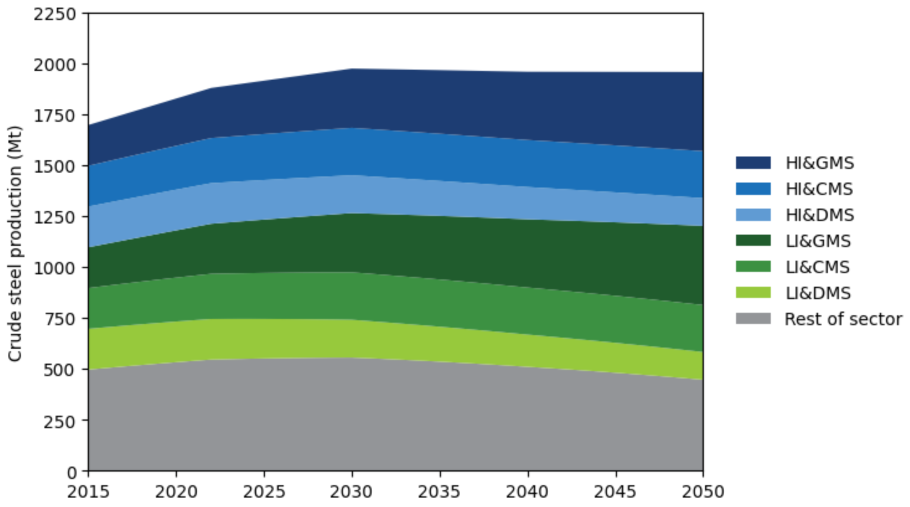
[21] Randers (2012) claims that using gross profit ("value added") rather than another denominator such as revenue is preferable because it is consistent with gross domestic product (GDP): "this paper focuses on value added because the nation's GDP is the sum of the value added of all its corporations. Although value added is the central concept in GDP, value added is surprisingly unknown in the corporate world and among business economists. […] It will take time to make value added as familiar as other denominators like "per sales, 'per ton of production', or 'per USD of operating profit'".

[22] In this case, the decarbonization benchmark can be absolute or based on economic denominator, but not on production as the units are specific to each sector.

[23] These sectors correspond to the sector split in IEA NZE 2050 scenario. Note that sector treatment can be applied with production denominator, but also with revenue or gross profit.

Exhibit 3. Input data for six hypothetical steel companies

Company	Reference year (2015)			Year-on-year market share growth	Abbreviation
	prod (Mt crude steel)	S1 (Mt CO2)	S1/prod (t CO2/t crude steel)		
High intensity & growing market share	200	500	2.50	1.5%	HI&GMS
High intensity & constant market share	200	500	2.50	0%	HI&CMS
High intensity & decreasing market share	200	500	2.50	-1.5%	HI&DMS
Low intensity & growing market share	200	200	1.00	1.5%	LI&GMS
Low intensity & constant market share	200	200	1.00	0%	LI&CMS
Low intensity & decreasing market share	200	200	1.00	-1.5%	LI&DMS
Rest of sector	496	274	0.55	0%	Rest of sector



Source: author calculation. Based on theoretical companies defined by Krabbe *et al.* (2015).

Intensity reduction is the seminal approach introduced by Randers (2012). Interestingly, the author introduces the intensity reduction by searching for a “fair share” approach: “*[h]ow much must I reduce my greenhouse gas emissions if I want to do my fair share to contribute towards the global effort to keep global warming below a 2 °C […]?*”. Randers envisages three solutions for reducing global emissions: proportional cuts through legislation (e.g. ask everyone to cut 50% by 2050, which amounts to a reduction of 1.7% per year), pricing of emissions through quota trading, and voluntary reductions. Pointing out that the first solution is neither cost efficient nor fair, and that quotas are difficult to implement, the author focuses on the third solution and seeks to determine by how much companies would have to reduce their intensity for the overall absolute reduction targets to be met. In order to halve emissions between 2010 and 2050 while maintaining a gross domestic product (GDP) growth rate of 3.5%, Randers proposes a reduction of GHG emissions per unit of GDP by 5% per year at company level[24].

$$BEI_{i,t} = EI_{i,t=ref} \cdot \left(1 + \frac{EI_{s,t} - EI_{s,t=ref}}{EI_{s,t=ref}}\right)$$

With $BEI_{i,t}$ the benchmark emission intensity of company $\boldsymbol{i}$ for year $\boldsymbol{t}$, $EI_{i,t}$ its historical emission intensity, and $EI_{s,t}$ the emission intensity of the sector $\boldsymbol{s}$.

The second allocation option – convergence - was introduced by Krabbe et al. (2015). According to this approach, whatever their starting level, companies must converge towards a carbon intensity compatible with a given scenario. This is the approach recommended by the sector-based target setting methodologies of the Science-based target initiative (SBTi).

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[24] Although more “fair” than the absolute reduction evoked in his first lead, Randers warns that “whether it makes sense to ask all nations [and therefore companies] to cut their GHG/GDP ratio at the same rate.” is fundamentally a “political question of equity” and that this rate could be adapted depending on countries.

$$BEI_{i,t} = \left(EI_{i,t=ref} - EI_{s,t=horizon}\right)\left(\frac{EI_{s,t} - EI_{s,t=horizon}}{EI_{i,t=ref} - SI_{2050}}\right) + EI_{s,t=horizon}$$

While the convergence approach is recommended for sectors where physical intensity (emissions divided by production) trajectories have been developed, the SBTi proposes other methodologies, including the reduction of absolute emissions ("*contraction*[25]"), that is the model option if no denominator is defined.

$$BE_{i,t} = E_{i,t=ref} \cdot \left(1 + \frac{E_{s,t} - E_{s,t=ref}}{E_{s,t=ref}}\right)$$

With $E_{i,t}$ the historical (absolute) emissions of company for year , and $E_{s,t}$ the emissions of the sector s.

The third allocation option - fair share - has been introduced by PAT (2021) and formalized by Urban *et al.* (2021). It aims to combine the advantages of the convergence and reduction approaches: reasoning in terms of absolute emissions to guarantee the overall respect of the carbon budget while taking into account a denominator to reward the most efficient companies and allow them to develop their market share (inorganic growth) without being penalized[26]. The principle is to allocate each year's carbon budget on the basis of each company's market share. The authors use revenue to estimate the market share, but it is possible to use alternative denominators (production or gross profit).

$$BE_{i,t} = E_{i,t} \cdot \left(\frac{d_{i,t}}{d_{s,t}}\right)$$

What is the impact of each of these options - reduction, convergence and fair share - on companies' decarbonization efforts (their carbon budget)? For companies whose initial intensity is higher than that of the sector, we observe on the graph an "inverted Z" shape between the start and end points of the three benchmarks (blue lines in Exhibit 4): the reduction approach is the least restrictive for the company's carbon budget, while the convergence approach is more restrictive but adapts to its starting level; finally, the fair share approach is the most restrictive and requires a significant reduction in carbon intensity from the reference year onwards. Naturally, these results reverse for companies whose carbon intensity is below the sector average, forming a "Z" shape (green lines in Exhibit 4).

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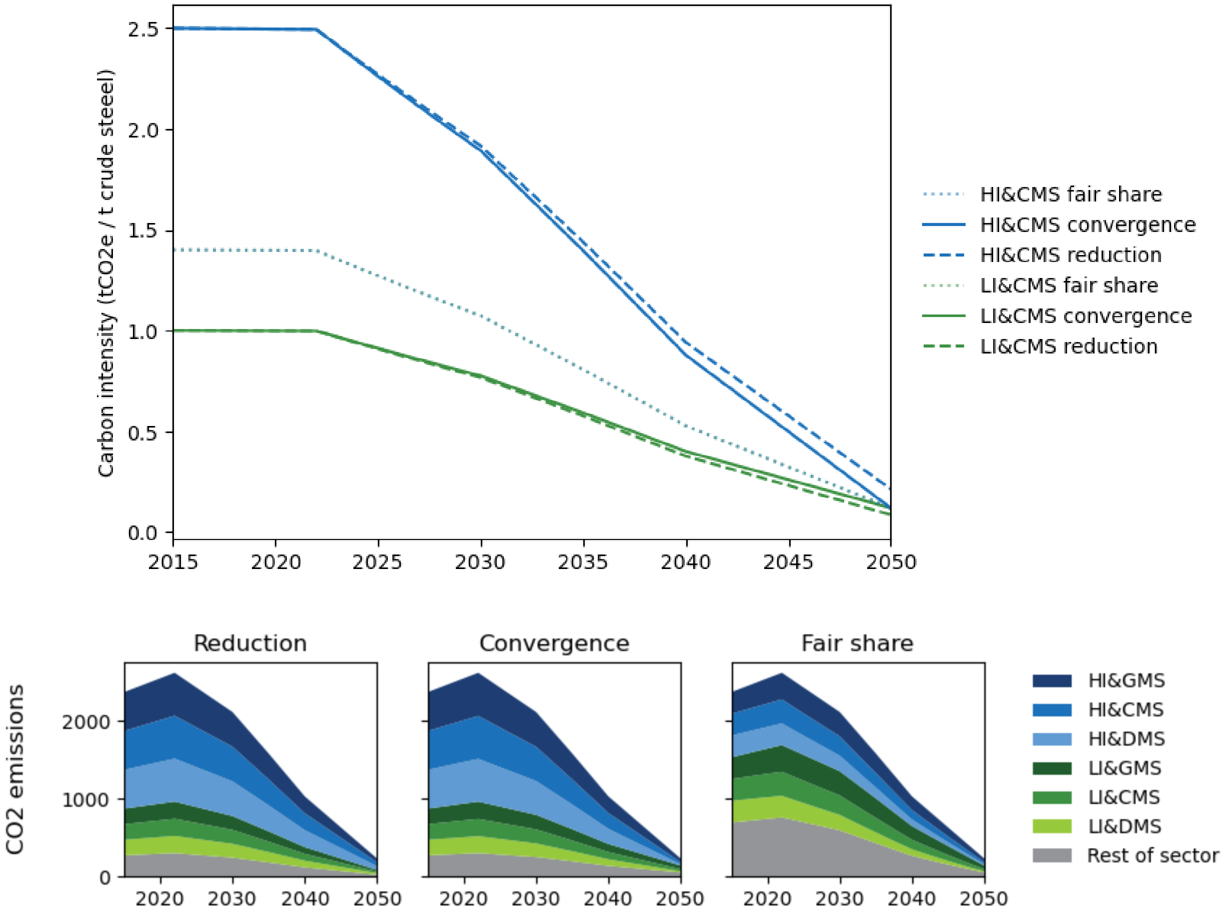
[25] where "all companies reduce their absolute emissions [...], irrespective of initial emissions performance, and do not have to converge upon a common emissions value. The contraction approach can be used with sector-specific or global emissions scenarios [...] The minimum annual linear reduction rates aligned with 1.5˚C and WB-2˚C are 4.2% and 2.5%, respectively". From "Foundations of Science-based Target Setting v1.0" (p.8, p.20).

[26] Urban et al. (2021) takes the example of the acquisition of an entity by company A: "the acquisition increases the market share of Company A. [...] Its reported emissions – unadjusted for these changes in market share – will accordingly show a similar spike in its emissions, as its reported emissions will now include both its original emissions and those of the entity it has acquired. Absent a correction, this spike would push the company's emissions well in excess of its benchmark, and prevent it from meeting its carbon budget, even if all assets owned by the company are still aligned with a rapid decarbonisation. The solution we propose involves the adjustment of Company A's reported emissions by integrating the trend in market share into the calculation. Specifically, if from one year to the next the company's market share doubles, the adjustment would reduce the company's raw emissions by half, to give a market-neutral trend that reflects the rate of emissions attributable to the company at its baseline market share." (p.10).

Exhibit 4: Comparison between convergence, reduction and fair share allocation



Source: author calculation.

The last two parameters for defining the benchmark are related to the model timeframe.

The reference $t = ref$ year corresponds to the year from which the benchmark (and trajectory) are calculated. All overshoot/undershoot strictly before this date will not be considered. Another way to understand reference year is that it should always be possible to be aligned *after* this date. The reference year should not be confused with the analysis year $(t = ay)$, which corresponds to the last year for which historical data is available. Before this year, data is considered as historical, while after this year, data is considered as projected. For example, analysis year 2021 means that available data run until 2021 but the reference date can be 2015 or 2020.

The horizon $t = hor$ corresponds to the date up to which the overshoot will be calculated, *i.e.* the date up to which the model will calculate a benchmark and project a trajectory for the company[27]. In this first exercise, we consider only horizons between 2030 and 2050.

2.3 Projecting the company greenhouse gas emissions trajectory

Given the emission metric defined for the benchmark, the model projects the company greenhouse gas emissions trajectory based on parameters related to the denominator projection and the emission intensity projection.

The trajectory concerns at least the emissions projection, but also the denominator projection if parameter 6 includes one. There are several ways of estimating trajectories for a company. These choices must be dictated by the availability of historical data and company forecasts.

The denominator projection parameter allows to choose whether the market share corresponding to the denominator (production, revenue or gross profit) is considered constant at its value of the analysis year $t = ay$,

$$d_{i,t} = d_{s,t}.\left(\frac{d_{i,t=ay}}{d_{s,t=ay}}\right)$$

---

[27] It should not be confused with the date to which the temperature increase corresponds (2100).

or evolves according to its historical trend $\overline{\Delta md_\iota}$ - calculated between first year with data available $t = fy$ and analysis year $t = ay$ - over the 5 years following the analysis year[28].

$$\overline{\Delta md_\iota} = \sum_{t=fy+1}^{ay} \frac{1}{ay-(fy+1)} . \left(\frac{\frac{d_{i,t}}{d_{s,t}} - \frac{d_{i,t-1}}{d_{s,t-1}}}{\frac{d_{i,j-1}}{d_{s,t-1}}} \right)$$

$$d_{i,ay+1\leq t\leq ai+5} = d_{s,t} . \left(\frac{d_{i,t-1}}{d_{s,t-1}} \right) . (1 + \overline{\Delta md_\iota})$$

$$d_{i,t>ai+5} = d_{s,t} . \left(\frac{d_{i,t=ay+5}}{d_{s,t=ay+5}} \right)$$

In a similar way, the intensity projection parameter allows to choose whether the emission intensity is considered constant at its value of the analysis year $t = ay$,

$$EI_{i,t} = EI_{i,t=ay}$$

or evolves according to its historical trend $\overline{\Delta EI_\iota}$ over the 5 years following the analysis year.

$$\overline{\Delta EI_\iota} = \sum_{t=fy+1}^{ay} \frac{1}{ay-(fy+1)} . \frac{EI_{i,t} - EI_{i,t-1}}{EI_{i,t-1}}$$

$$EI_{i,ay+1\leq t\leq ai+5} = EI_{i,t-1} . (1 + \overline{\Delta EI_\iota})$$

$$EI_{i,t>ai+5} = EI_{i,t=ay+5}$$

A third option for the intensity projection parameter is to take into account whether the company has set emission reduction targets. In its current version, the model does not consider the specificities of these targets (horizon, scope, intensity or absolute), but relies on the same parameters as the benchmark to compute the intensity trajectory. Whatever the parameters, intensity will therefore be considered as aligned between the analysis year and the horizon (but not necessarily between the reference and analysis years). Beyond the fact that this first approximation does not take into consideration the specificities of the targets set by the company, it makes the simplifying assumption that the intensity trajectory will be similar to that of the scenario and not linear (cf. Box 1).

Box 1: Linear vs. scenario trajectories in company emission reduction targets

The target set by the company is the reduction between a reference year and a horizon. Let us take the example of a company in the Power Utilities sector with an intensity of 1tCO2e/MWh in 2020 and a target of 0.13 tCO2e/MWh in 2035 (Figure), the reduction target is -87% (a). This trajectory is generally monitored by linearizing the reduction over the period. However, the intensity reduction of the scenario might not be linear. If it is convex, then a linear trajectory between the reference and horizon dates will tend to generate an overshoot despite the target being “aligned”. The same reasoning applies in the case of an absolute contraction approach (b). If alignment is measured over time (in opposition as point-in-time), being aligned with a linear trajectory does not guarantee consistency with the carbon budget over the period.

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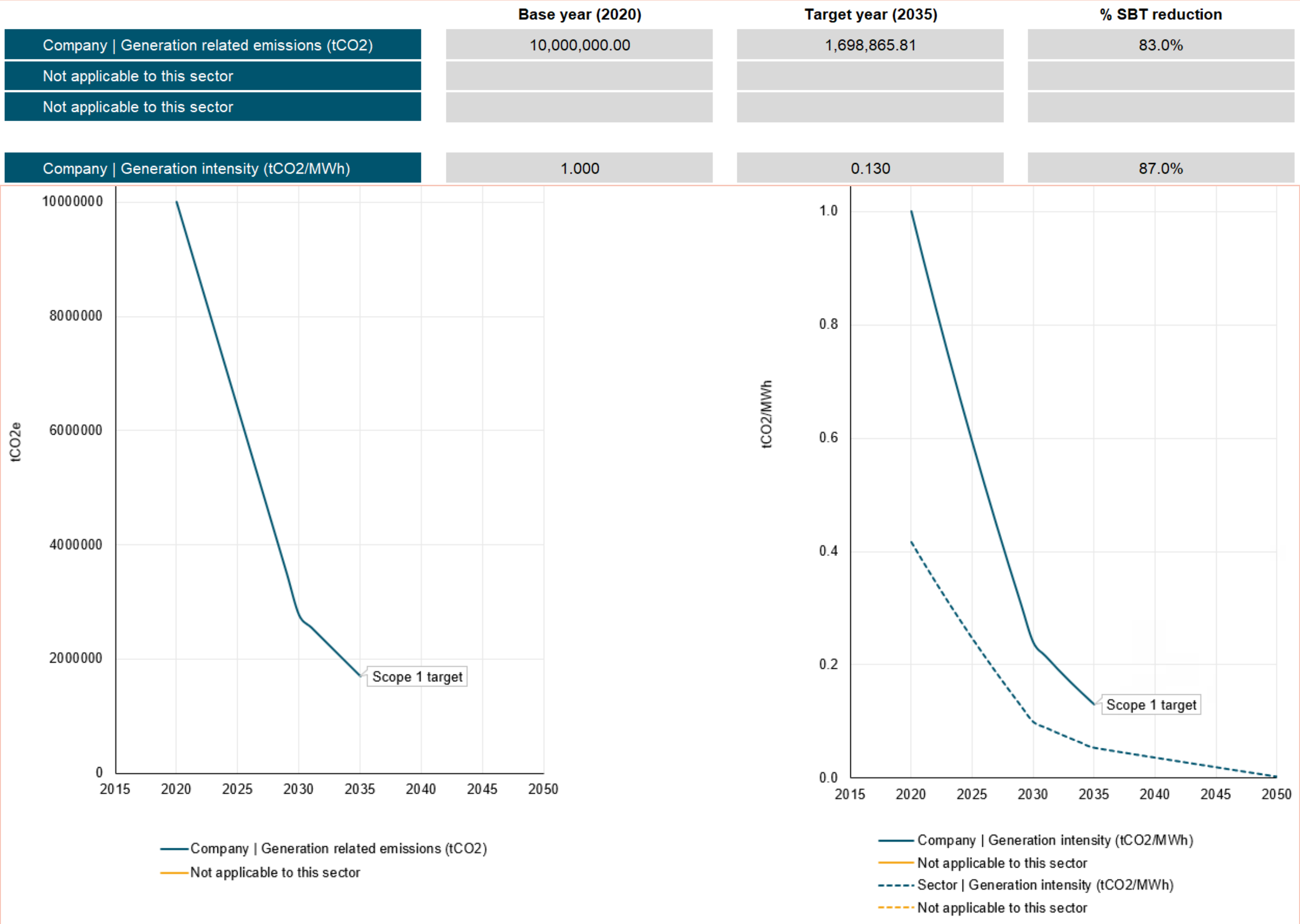
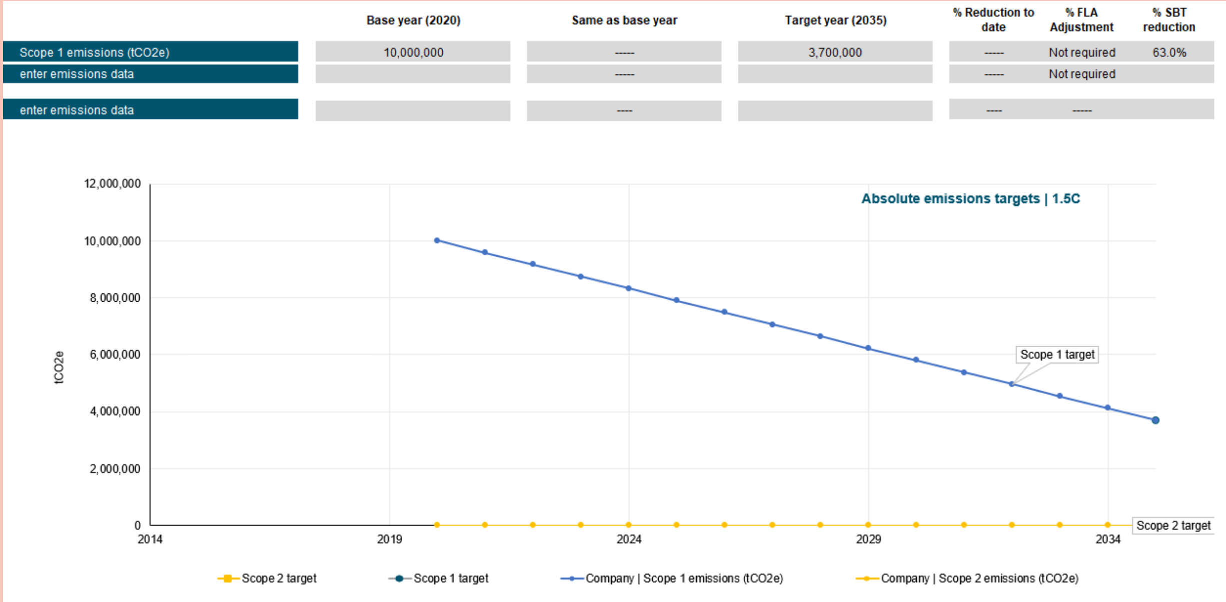
[28] In this version of the model, we have limited projections to 5 years in order to be consistent with the historical depth of available data: historical emissions data, particularly for scope 3, are very rarely available beyond 5 years.

a) Convergence Approach (*“Sectoral Decarbonization Approach”*)



	Base year (2020)	Target year (2035)	% SBT reduction
Company | Generation related emissions (tCO2)	10,000,000.00	1,698,865.81	83.0%
Not applicable to this sector			
Not applicable to this sector			
Company | Generation intensity (tCO2/MWh)	1.000	0.130	87.0%

b) Reduction Approach (*“Absolute contraction approach”*)



	Base year (2020)	Same as base year	Target year (2035)	% Reduction to date	% FLA Adjustment	% SBT reduction
Scope 1 emissions (tCO2e)	10,000,000	-----	3,700,000	-----	Not required	63.0%
enter emissions data		-----		-----	Not required	
enter emissions data		----		----	-----	

Example of a target-setting simulation of scope 1 emissions for a power utility company using scenario SBTI 1.5C, with base year = 2020, base year activity output = 10 000 000 MWh, base year generation-related emissions = 10 000 000 tCO2e with target year 2035 and fixed market share (Science-based Target setting tool Version 2.2).

2.4 Assessing company/portfolio overshoot and ITR

The model calculates an emission alignment metric (overshoot or ITR) at company or portfolio level based on the benchmarks and trajectories of each company. This calculation depends on the growth treatment and the assessment time management parameters. When calculating the alignment metric at portfolio level, it also depends on the aggregation and the weighting metric parameters. Finally, if calculating an ITR, the ITR method and transient climate response to cumulative emissions value parameters are also considered.

The growth treatment parameter defines the extent to which a company's growth should be neutralised in the calculation of its overshoot.

The first option corresponds to the normative hypothesis that the company growth (or degrowth) should not impact the efforts of the company: two companies that have the same intensity should have the same overshoot whatever their denominator growth. In such option, the global carbon budget is not guaranteed, since if all companies see their denominator grow faster than the global denominator, absolute emissions will exceed the budget associated with the scenario despite the alignment of companies in terms of intensity. In this option, the transition from intensity to absolute emissions (whether for the benchmark or the trajectory) is made by considering a denominator that follows the sector's trend (Appendix, Exhibit 16).

The second option corresponds to the normative hypothesis that the company's intensity target needs to be adjusted to its growth, *and* that this growth is a market-share growth (inorganic growth), i.e. that the other companies of the sector will have market share decrease so that the market size of a given sector remain consistent with the scenario. This second option corresponds to the adjustment proposed by Krabbe *et al.* (2015) to deal with the issue of changing market shares: "*[t]he intensity pathways of the fast-growing companies are steepened to account for their increase in market share. If this is not accounted for, the sector average intensity will increase owing to the growth, resulting in an exceedance of the sector's carbon budget. The opposite happens to the intensity pathways of the companies that show a decreasing market share*[29]." For this second option, we define a growth adjustment factor $GA_{i,t}$

$$GA_{i,t} = \frac{\dfrac{d_{i,t=ref}}{d_{s,t=ref}}}{\dfrac{d_{y,t}}{d_{s,t}}}$$

In the case of the convergence attribution, the benchmark is adjusted as follow[30] (Exhibit 5).

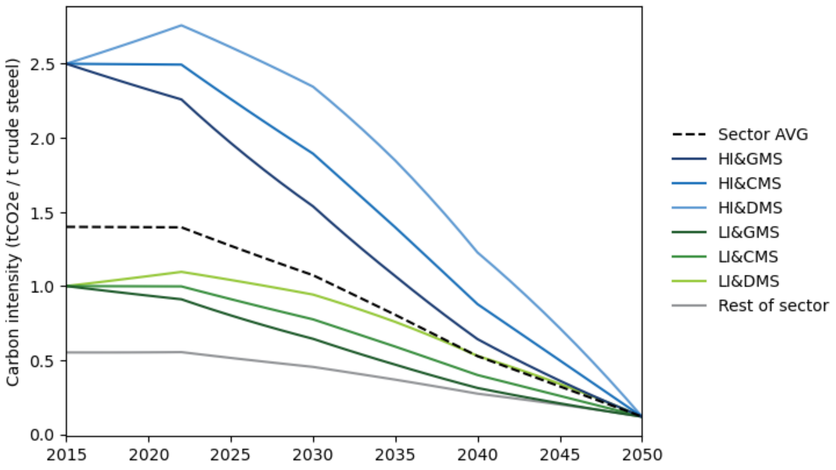
$$BEI_{i,t} = \left(EI_{i,t=ref} - EI_{s,t=horizon}\right)\left(\frac{EI_{s,t} - EI_{s,t=horizon}}{EI_{i,t=ref} - SI_{2050}}\right) GA_{i,t} + EI_{s,t=horizon}$$

---

[29] Krabe et al. (2015) justify this adjustment as follow: "*Although this might seem unrealistic or unfair, it makes sense from a business perspective, because when a company's market share is decreasing, it will probably invest less in new, more efficient technologies, and vice versa*."

[30] Note that SBTi also considers a "safeguard" to the market share parameter when a company projects a decrease in their activity leading to a reduce market share (Foundations of Science-based Target Setting, V1.0, p.8.): $GA_{i,t} = MAX(GA_{i,t}, 1)$.

Exhibit 5: Convergence allocation with adjustment for inorganic market share growth



Companies' convergence decarbonization benchmarks are adjusted to take account of their growth (or decline), on the assumption that these variations are only market share variations (second option of the growth treatment parameter). A company that is more (less) intensive than the sector with a growing market share must reduce its intensity more (less) rapidly. Source: author calculation.

In the case of the intensity reduction attribution, according to Randers (2012), as long as global GDP growth is indeed 3.5% per year, the fact that some companies have higher growth than others (in terms of gross profit) is not a problem if they align with their intensity benchmark: "*if the company succeeds in reducing its GEVA* [GHG emissions per unit of value added] *by 5% per year, but grows at 7% per year in the process, its GHG emissions will increase by 2% per year. This does not invalidate the conclusion of this paper, because corporations on average will only grow at 3.5% per year. It is true that some corporations will grow faster than 3.5% per year and increase their absolute emissions. But others will grow less fast, or even decline, and reduce their absolute emissions. The total value added of all corporations will, per my central assumption, increase by 3.5% per year.*" While we recognize that an average intensity reduction value provides a satisfying approximation, it does not necessarily guarantee that emission reduction targets will be met, despite the assumption of overall growth (Exhibit 6). It is therefore necessary to adjust the benchmark as follow[31]:

$$BEI_{i,t} = EI_{i,t=ref} . \left(1 + \frac{EI_{s,t} - EI_{s,t=ref}}{EI_{s,t=ref}}\right) . GA_{i,t}$$

In the case of the fair share attribution, the growth treatment parameter is necessarily set to this second option, as the budget is calculated each year according to the company's market share.

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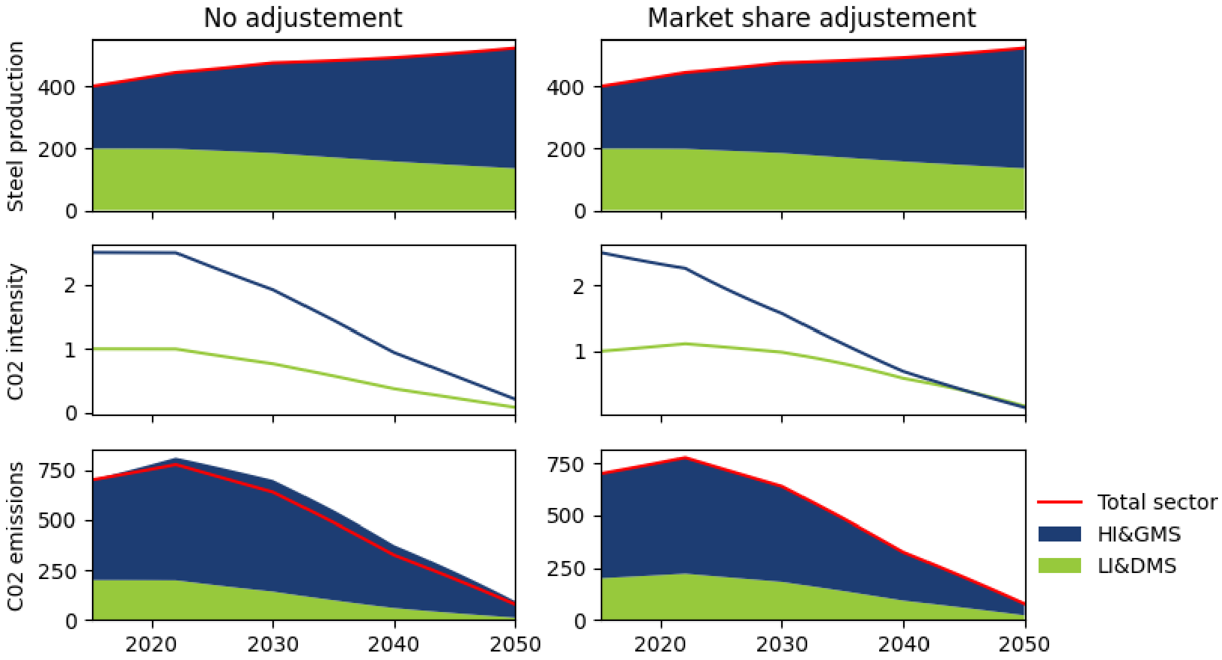
[31] This adjustment leads to the same benchmark as for the absolute contraction approach (in the example of Exhibit 6, both companies reduce by 88.9% their absolute emissions).

Exhibit 6: Reduction allocation without and with adjustment for market share growth



We consider a scenario where steel production results solely from the production of the theoretical companies HI&GMS and LI&DMS (see Exhibit 3 for references). At sector level, the intensity is reduced by 91.5%. If we impose this reduction rate on the two companies - whose market shares offset each other - we obtain absolute emissions higher than those predicted by the scenario (left). This is due to their different emission intensities at the reference date. Following a similar approach of market share adjustment developed for the convergence approach, it is possible to adjust the rate of reduction of both companies to consider their market share evolution (right). Source: author calculation.

The third option corresponds to the normative hypothesis that the company's intensity target needs to be adjusted to its growth, and that this growth might contribute to the sector growth (organic growth). In this option, a company with an important economic growth will have to provide more decarbonation efforts to remain in its budget. This third option requires no adjustment to the intensity benchmark, but rather to the denominator used to define the absolute benchmark. In this case, we use the company denominator projected according to the scenario trend.

The assessment time management parameter defines how overshoot is calculated over several years. The first option is to calculate an overshoot over the whole period and then to multiply it with the global carbon budget of the scenario for the same period (budget option). The second option is to compute the overshoot year by year and to apply it to the carbon budget year by year. The two options lead to the same results if the reduction rate of the benchmark equals the reduction rate of the global economy. However, if the reduction rate of the economy is higher than the one of the benchmark, then the budget approach gives generates higher overshoot.

The aggregation parameter influences how the portfolio overshoot/ITR is calculated given company overshoot/ITR. The first option is to calculate an overshoot at the portfolio level by aggregating companies' benchmarks and trajectories. The second option is to calculate the portfolio overshoot/ITR as the weighted average of companies' alignment metric.

If this second option is chosen, the weighing metric parameter defines which company characteristic is used to weight its contribution to the portfolio alignment metric. The seven options corresponding to different characteristics are based on the options defined by CDP and WWF (2020): financial weight, total emissions, market owned emissions, enterprise owned emissions, enterprise value including cash, total assets, or revenue.

The remaining two parameters are specific to the calculation of an ITR and do not impact company or portfolio overshoot. The first is the method used to convert the overshoot to a temperature rise. In the current version of the model, the only option is to use a transient climate response to cumulative CO_2 emissions (TCRE) formula, however, a second option is under development to use a more complex climate model[32]. The TCRE is used to convert an overshoot $O_{(i\ or\ p)}$ – already translated from company or portfolio level to the global economy level - into an averaged

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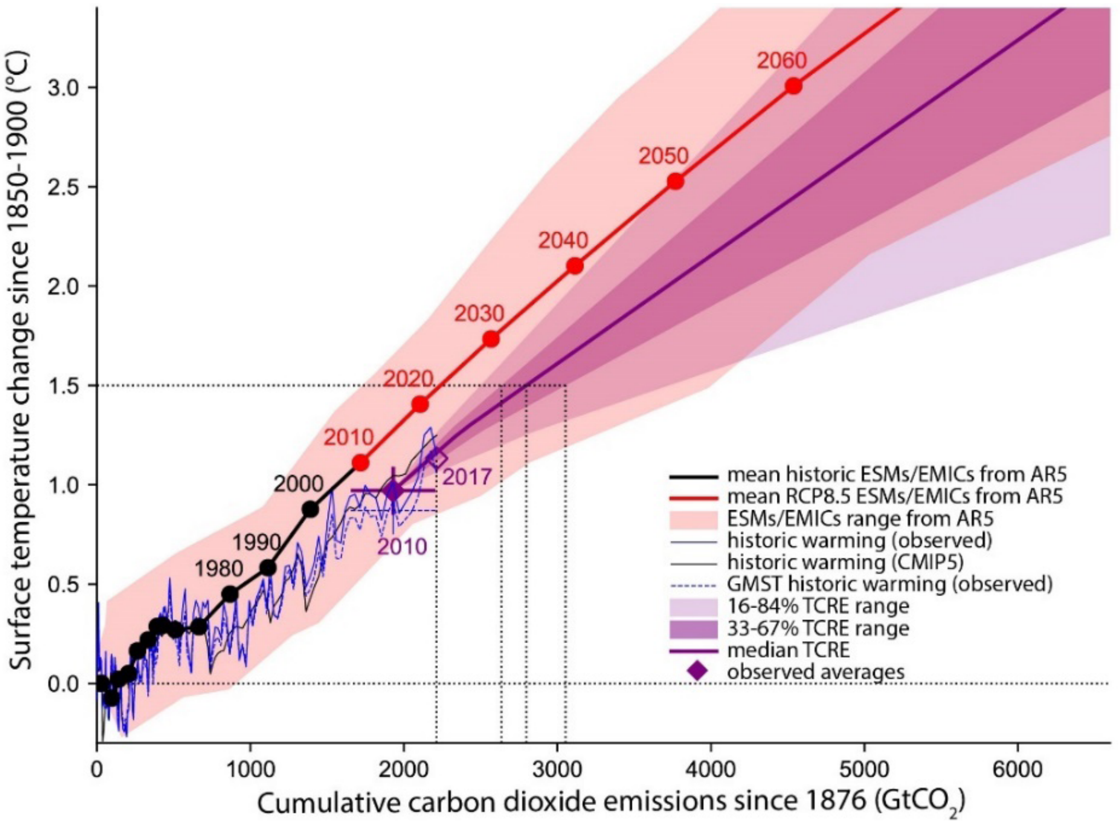
[32] More precisely the FAIR model, whose documentation is available at: https://gmd.copernicus.org/articles/11/2273/2018/ (visited on 22 April 2024).

near-surface air temperature response, by multiplying an excess carbon budget given that this relation is relatively linear (Exhibit 7).

$$ITR_{(i\ or\ p)} = 1.5°C + O_{(i\ or\ p)}.Global\ Carbon\ budget_{1.5°C}.TCRE$$

The TCRE value parameter is directly linked to this option. The TCRE can be estimated from climate models or from observations. In both cases, the uncertainties surrounding its value remain significant (see MacDougall, 2016, for a review). PAT (2021) used the value of the Intergovernmental Panel on Climate Change (IPCC) 5th assessment report (0.545 °C per 1000 $GtCO_2$). According to the 6th report published in 2023, "*the TCRE falls likely in the 1.0 °C–2.3 °C per 1000 PgC range, with a best estimate of 1.65 °C per 1000 PgC. This is equivalent to a 0.27 °C–0.63 °C range with a best estimate of 0.45 °C when expressed in units per 1000* $GtCO_2$[33]").

Exhibit 7. Linear relation between cumulative carbon emissions and temperature change



The relationship between cumulative emissions and the average increase in surface temperature is relatively linear, which justifies the method of calculating ITR using a transient climate response to cumulative CO2 emissions. Source: IPCC special report 1.5 °C - FIGURE 2.3 - Temperature changes from 1850–1900 versus cumulative CO2 emissions since 1st January 1876.

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[33] P.94 of the technical summary available at: https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_TS.pdf (visited on 29 April 2024).

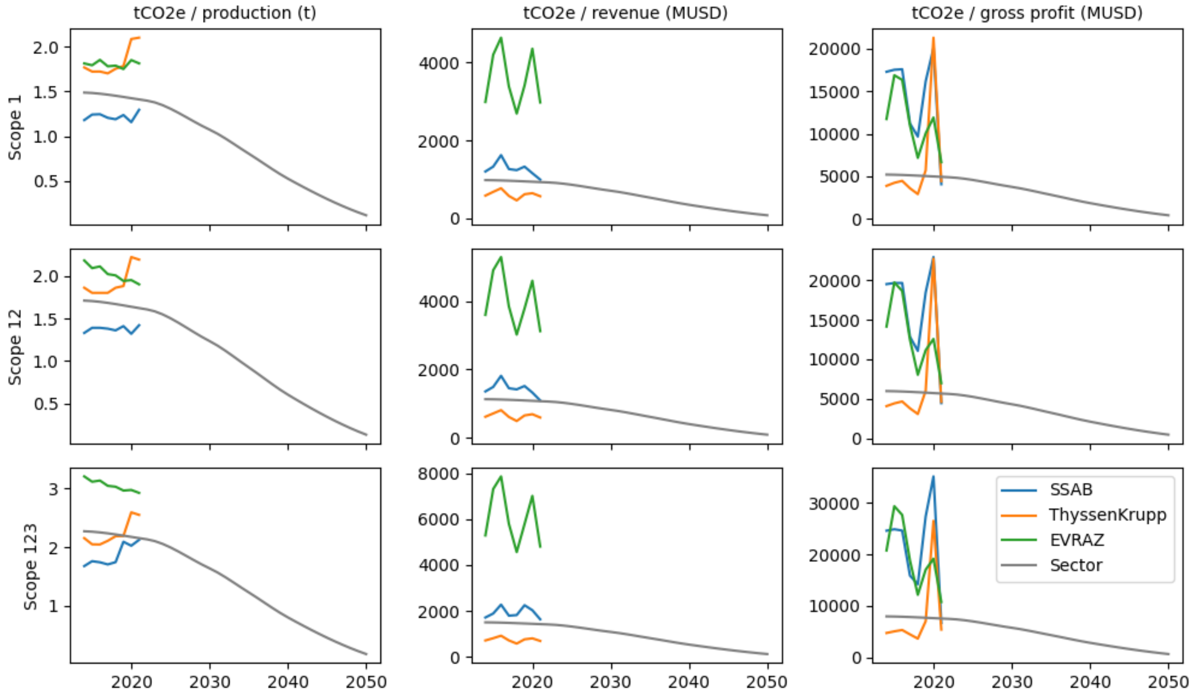
AN EMPIRICAL ILLUSTRATION OF THE SENSITIVITY ANALYSIS FRAMEWORK ON THREE STEEL COMPANIES

In this section, we discuss and compare the existing options for the decarbonization allocation parameter, i.e. the reduction, convergence, absolute reduction and fair share approaches. An Empirical illustration of the impact of model parameters on the ITR of three steel companies

In the previous section, we have seen the impact of allocation choices on the construction of benchmarks at company level from a theoretical point of view. In this section, we extend these results by looking at the other model's parameters that influence a company ITR based on real data for three steel companies: Evraz (EV), SSAB (SB), and ThyssenKrupp (TH). The choice of these companies is motivated by the availability of data and their different emission profiles. When looking at the emission intensity on scope 12[34], EV and TH have a production intensity higher than the sector average, but EV intensity is decreasing while TH intensity is increasing. SB has an intensity lower than the sector average and relatively constant (Exhibit 8).

In order to test the impact on these three companies of the different options available for each parameter, we first define a reference analysis configuration (4.1). We then analyse the impact of the different options for one parameter - all other things being equal - i.e. keeping the options defined in the reference configuration for the other parameters. As in section 2, the results of the analysis of parameters are divided into three parts: parameters that influence the decarbonization benchmark (at company level), parameters linked to the construction of its trajectory, and parameters linked to the calculation of the ITR.

Exhibit 8: Historical intensity by scope and denominator of three steel companies



Source: author calculation.

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[34] Which is the relevant scope for the steel sector, see Exhibit 2.

3.1 Reference configuration

To measure ITR deviations resulting from the different options available for each parameter, we define a reference configuration (Exhibit 9).

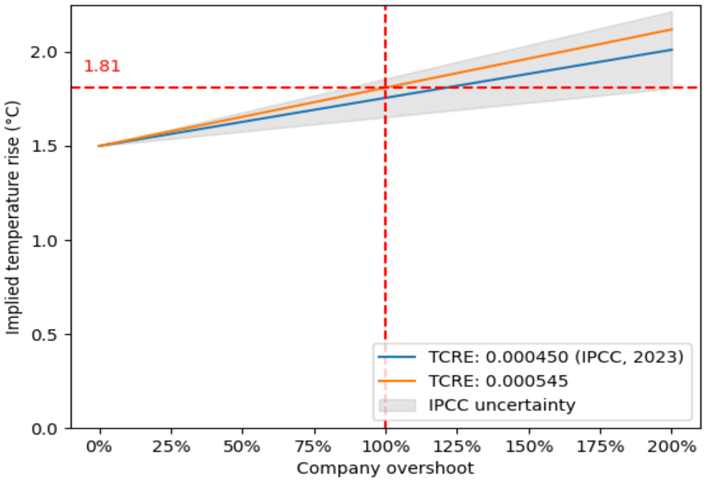
Exhibit 9: Reference configuration

Parameter	Reference option
Allocation	Convergence
Horizon	2050
Reference year	2015
Sector treatment	True
Greenhouse gas emissions scope	Relevant
Denominator	Production
Market share growth treatment	Neutral
Market share projection	Constant
Intensity projection	Constant
TCRE	0.000545
ITR time management	Budget

In this reference configuration, we observe ITR between 1.66 et 1.78 °C for the three steel companies (Exhibit 11). These ITR may seem low at first glance. However, they can be explained by two characteristics of the carbon budget approach[35].

The first characteristic is the coefficient between overshoot and ITR (Exhibit 10). The relationship is linear, but the coordinate at the origin is already 1.5 °C and the coefficient is low: a 100% overshoot, i.e. a carbon budget twice as large as that allocated in a 1.5 °C scenario, “only” leads to an ITR of 1.8 °C. On a global level, the remaining carbon budget[36] from 2020 for a 50% chance of limiting warming to 1.5 °C was 500 $GtCO_2$, while the budget for limiting warming to 2 °C was 1150 $GtCO_2$, which represents an overshoot of 130%. There’s no question here about challenging this linear equation. However, it is important to realize that, in terms of communication, saying that a company is at 1.8 °C rather than 1.5 °C may seem less alarming than saying that it is 100% over its 1.5 °C carbon budget.

Exhibit 10: Relation between overshoot and implied temperature rise



The transient climate response to cumulative CO2 emissions (TCRE) is used to convert an overshoot – translated from company or portfolio level to the global economy level - into an averaged near-surface air temperature response, by multiplying an excess carbon budget. Source: author calculation.

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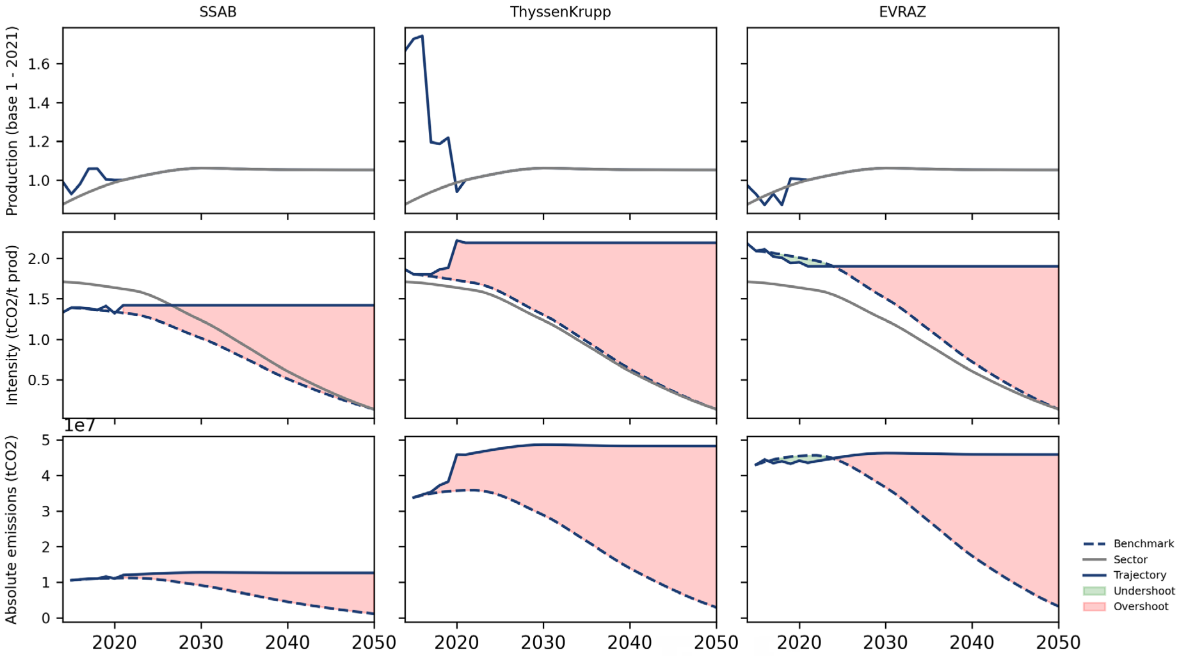
[35] The sensitivity analysis presented in this report focuses solely on this type of approach, recommended by PAT (2021). However, there are other approaches, such as regression or scoring (ILB, 2024).

[36] From the Intergovernmental Panel on Climate Change « Climate change 2023 Synthesis Report » (p.82).

The second characteristic is the horizon considered for the overshoot: limiting the horizon to 2050 tends to limit the overshoot to around 100%. Whatever the starting point of emissions in the reference year, if we consider a linear trajectory towards net zero emissions in 2050, the area between the trajectory and the benchmark (in red in Exhibit 11) will very rarely be greater than the area under the benchmark[37], leading to an overshoot of less than 100%[38]. For these reasons, in the remainder of this section we will focus on analysing overshoot deviations rather than ITR.

Exhibit 11: ITR of three steel companies in the reference configuration



	SSAB	ThyssenKrupp	EVRAZ
Overshoot ref (Horizon=2050)	69.2%	101.7%	56.6%
ITR ref (Horizon=2050)	1.69 °C	1.78 °C	1.66 °C

Source: author calculation.

3.2 Parameters that influence the decarbonization benchmark

The first parameter influencing benchmark construction is the horizon. While not extending the horizon beyond 2050 tends to limit overshoot to around 100% (*cf. supra*), reducing it has a significant impact on overshoot. Keeping the (conservative) assumption of constant emission intensity, moving from a 2050 to a 2030 horizon significantly reduces overshoots for all three steep companies, up to over 70% (Exhibit 12). The advantage of a closer horizon, however, is that projections might be more accurate (2030 is regularly used by companies to set their near-term targets). While an intermediate result to 2030 may be interesting, in particular for shareholder engagement, it should be complementary to a result to 2050.

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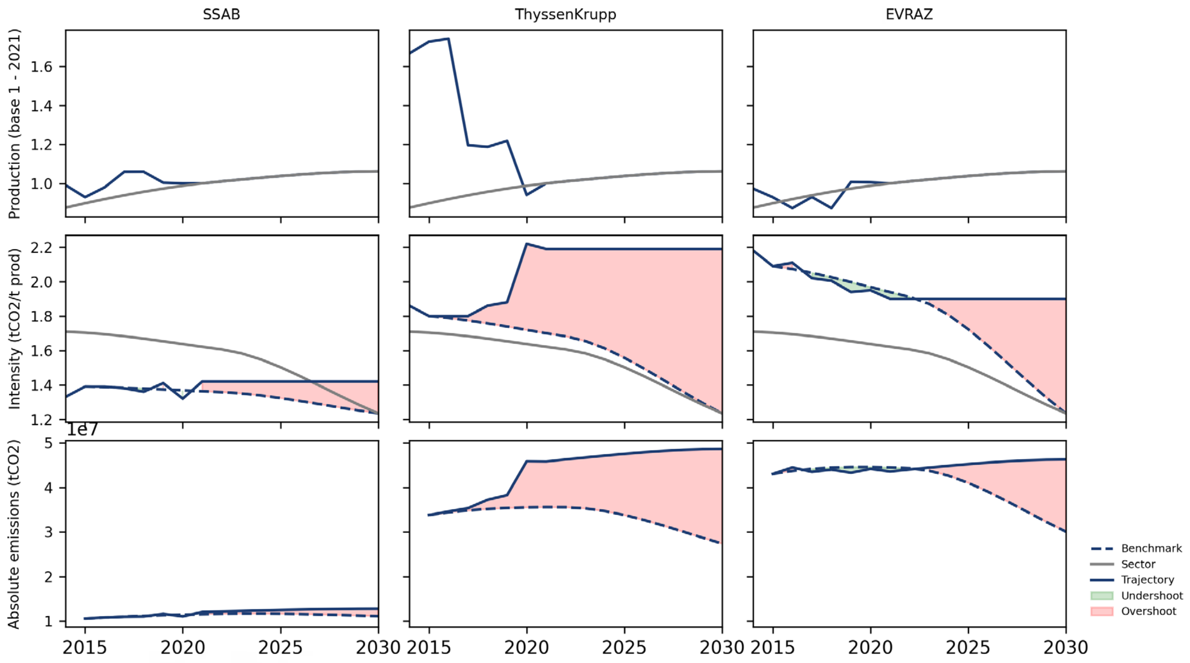
[37] In the reference configuration we take the conservative hypothesis of constant emissions.

[38] To overcome this limitation, it would be possible to consider a more distant horizon (e.g. 2100). However, the choice of this horizon becomes arbitrary, unlike the 2050 horizon shared by many regulatory and voluntary frameworks, and projections are increasingly difficult to make the more distant the horizon.

Exhibit 12: Impact on overshoot of different horizons

a) Horizon 2030



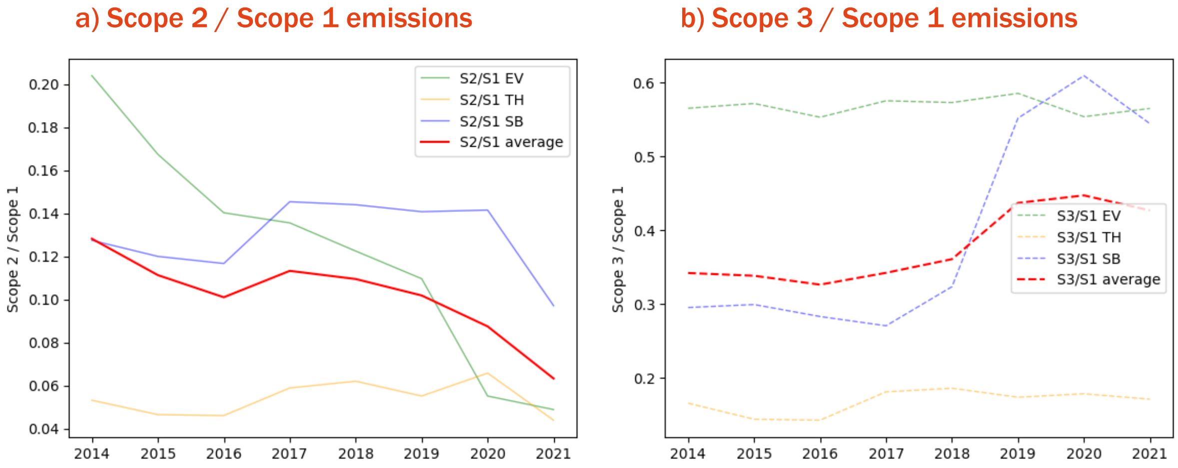
	SSAB	ThyssenKrupp	EVRAZ
Overshoot ref (Horizon=2050)	69.2%	101.7%	56.6%
ITR ref (Horizon=2050)	1.69°C	1.78°C	1.66°C
Overshoot (Horizon=2030)	5.3%	31.1%	9.4%
ITR (Horizon=2030)	1.51°C	1.59°C	1.53°C
Overshoot variation (Horizon)	**-63.9%**	**-70.7%**	**-47.2%**

Source: author calculation.

The choice of reference date is less often discussed than the horizon in the literature. We show that it has less impact on overshoot for the three steel companies (Appendix, Exhibit 19). However, it's an important choice in terms of the message it sends to companies. Calculating benchmarks dynamically on the basis of updated carbon budgets, i.e. systematically take the last year with available data as the reference year, tends to ignore companies past behaviour, whether in terms of their efforts or their lack of consideration for greenhouse gas emissions. For SB and EV, which were fairly well aligned with their respective intensity trajectories between 2015 and 2020, shifting the reference date to 2020 tends to increase their overshoot by approximately 20%. Conversely, for TH, whose intensity has increased between 2015 and 2020, this tends to reduce its overshoot by approximately 20%. Although the most important thing is the efforts expected in view of the remaining carbon budget, not taking past efforts into account seems to provide little incentive for companies. That's why, in the initial configuration, we chose to consider 2015 - the year of the Paris Agreement - as the reference date: we consider that by then companies already had the knowledge and tools they needed to set emissions reduction targets.

The question of scope, and in particular whether or not to include scope 3, is recurring in climate finance. For our three companies, considering only scope 1 or scope 1, 2 and 3 rather than scope 1 and 2 has a relatively limited impact (at most +27%, see Appendix, Exhibit 20). However, these results are specific to these companies, to this sector and to certain scenario modelling choices. Indeed, we can see that for each company, the scope has no influence on whether it is located above or below the sector intensity (Exhibit 8, first column). Only the historical trend has an impact: for SSAB, scope 123 emissions have tended to increase, while scope 12 and scope 1 emissions are relatively constant. Its overshoot naturally increases when scope 3 is included. The limited impact of the scope parameter on these companies can also by explained by the fact that the steel sector emissions are concentrated mostly scope 1 emissions with a scope 2 / scope 1 ratio below between 5 and 20% for the three companies (Exhibit 13a).and a scope 3 / scope 1 ratio between 10 and 60% (Exhibit 13b). Finally, the scenario used does not provide a differentiated trajectory for each perimeter for each sector. We had to approximate the sectoral trajectories of the scopes not covered, based on existing company ratios (see appendix): whatever the scope, the trajectories therefore have the same shape, which reduces the impact of this parameter on companies. More granular work at scenario level would enable these trajectories to be better differentiated.

Exhibit 13: Ratios of emissions under different scopes

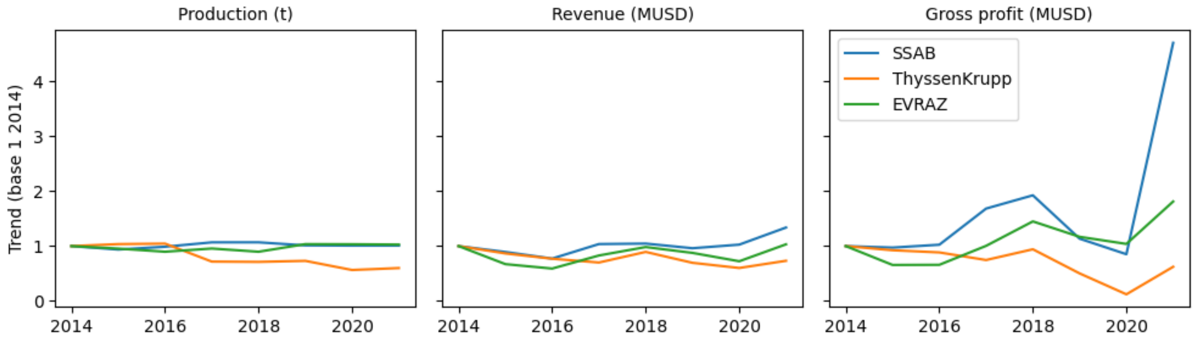

a) Scope 2 / Scope 1 emissions

b) Scope 3 / Scope 1 emissions

Source: author calculation.

The impact of the denominator used to calculate intensity has a very significant impact on overshoot (over 110% for SSAB, see Appendix, Exhibit 21). The greatest deviations are obtained when the denominator is gross profit, which is explained by the fact that this is the most volatile variable (Exhibit 14). For SB, for example, gross profit has risen sharply in 2021, considerably reducing its intensity (projected as constant after 2021). A year earlier, however, its intensity was above the benchmark. Although gross profit has its advantages, in particular the fact that in aggregate it can be equated with GDP (Randers, 2012), it also has the disadvantage of being more volatile. When taking a sectoral approach, it therefore seems preferable to use production as the denominator, as it is less sensitive to price fluctuations and cyclical economic variations.

Exhibit 14: Trend and volatility comparison for different denominators



Source: author calculation.

The type of allocation has a relatively moderate impact on the three steel companies (Appendix, Exhibit 22). For the reduction option, the fact that initial intensities are relatively close to the benchmark means that switching to reduction rather than convergence has a limited impact. For the fair share option[39], we observe the effects presented in sub-section 3.5. For SB, whose initial intensity is lower than that of the sector, switching from convergence to faire share contributes to reducing its overshoot by around 30%. Conversely, EV, whose intensity in 2015 was higher than that of the sector, is penalized by the fair share approach and its overshoot increases by 35%.

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[39] Note that for the fair share approach, the growth treatment parameter is necessarily considered as organic or inorganic. In fact, the fair share principle is based on a distribution of effort that takes into account the evolution of companies' market share, so the «neutral» option is not applicable.

The treatment of a company's growth has a heterogeneous impact on the three companies: it is negligible for SB and EV but reaches over 90% for TH (Appendix, Exhibit 23). The main deviation comes from switching from the neutral option to one of the two remaining options - organic or inorganic - but the deviation between organic and inorganic is small. In the neutral option, only the positioning of the company's intensity in relation to that of the benchmark intensity is taken into account, and the fact that the company's market share is growing or decreasing has no impact on the calculation of either the benchmark or the overshoot. In this configuration, the multiplier used to transform benchmark intensity (respectively trajectory intensity) into absolute benchmark (respectively absolute trajectory) corresponds to the denominator to which the sector trend is applied. In the case of the steel sector, this trend is upward. However, for TH, the "real" trajectory is strongly downward between 2015 and 2021. The organic option - in which the benchmark intensity is not adjusted, and the real trajectory is used to calculate the absolute overshoot - considerably reduces its overshoot. More than a technical issue, the way in which growth is treated has an impact on incentives for companies, particularly for the sobriety lever.

3.3 Parameters that influence the company greenhouse gas emissions trajectory

The previous parameters had an impact on the company's benchmark definition. The second step in measuring ITR is to project its intensity and absolute trajectory. Two parameters are key in this step.

The impact of the market share projection parameter depends on the company growth treatment parameter. If growth is neutralized - which is the default option -, the way the market share is projected has no impact by definition. However, if we switch the growth treatment to "organic" in the reference configuration, the choice of projection has a decreasing impact for the three companies. This is due to the fact that their historical market shares have been decreasing before the last date available[40].

Finally, the intensity projection parameter has a very important impact (Appendix, Exhibit 25). In this exercise, we made the assumption that, if all three companies had climate targets, their intensity - after the last known date - would be aligned with the intensity benchmark of a convergence approach. As a result, the overshoot results only from the "known" intensity differences, i.e. the differences that occurred between the reference date and the last known year. The historical approach also has a significant impact, particularly for EV, which sees its overshoot become negative. However, these results are sensitive to the following underlying assumptions that could be changed: on the one hand, intensity is only projected over 5 years on the basis of the last 8 years available; on the other hand, it is assumed that the rate of evolution of intensity after these 5 years converges with the rate of intensity of the sector. Even so, these results show that the way in which business intensity is projected is one of the most important parameters.

3.4 Parameters that influence company/portfolio overshoot and ITR assessment

The last family of parameters has no impact on company overshoot calculation, but on the conversion of overshoot into ITR.

The value of the TCRE has a significant impact[41] due to the existing uncertainties on this physical parameter (Appendix Exhibit 26, see also Exhibit 7). This supports the suggestion made in the previous section to focus on overshoot rather than ITR, as this parameter should have no impact on company incentive behaviour.

The ITR time management parameter has a more limited and homogeneous impact between companies (Appendix Exhibit 27). However, it is not negligible and shows the importance of dynamics in the calculation of an overshoot: a 100% overshoot in the near future with still very high global emission levels does not have the same absolute impact as a 100% overshoot in the distant future with global lower emission levels.

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[40] Similar result is obtained with the growth treatment parameter set as "inorganic".

[41] The overshoot variation displayed is not the "real" overshoot deviation for each company - which is zero - but the temperature deviation translated into overshoot (based on Exhibit 10 – using TCRE=0.000545), so that we can compare these parameters with the other parameters.

CONCLUSION

The objective of this working paper is to propose an analytical framework extending the ILB (2020), PAT (2021), GFANZ (2022b) and ILB (2024) frameworks, to carry out quantitative analyses to better understand the deviations in ITR between the various existing methodologies, both at company and portfolio level.

To this end, we propose a generic model whose parameters are inspired by the design choices already identified in the literature, and particularly the recent review of ILB (2024). As it stands, the model proposes fifteen parameters, including eleven for which several options are presented in this study.

First, we show that it is preferable to compare overshoot rather than ITR due to the uncertainties surrounding the transient climate response to cumulative CO_2 emissions and the horizon considered. We then illustrate the flexibility of this framework by analysing company-level overshoot deviations for three steel companies (Exhibit 15).

Exhibit 15: Impact on overshoot of model parameters

	SSAB	ThyssenKrupp	EVRAZ	Average
Overshoot ref	**69.2%**	**101.7%**	**56.6%**	**75.8%**
Parameter	**Absolute overshoot deviation**			
Denominator	111.4%	63.6%	85.1%	**86.7%**
Intensity projection	68.7%	98.6%	62.7%	**76.7%**
Horizon	63.9%	70.7%	47.2%	**60.6%**
Growth treatment	4.2%	91.3%	5.5%	**33.7%**
Scenario linearization	28.8%	35.9%	28.6%	**31.1%**
Allocation approach	32.5%	1.3%	35.3%	**23.0%**
Reference year	20.0%	21.4%	20.3%	**20.6%**
Scope	26.9%	2.7%	15.8%	**15.1%**
Market share projection	7.0%	13.9%	5.4%	**8.8%**
TCRE value	32.2*%	50.1*%	28.6*%	**37.0%**
ITR time management	21.5*%	21.5*%	21.5*%	**21.5%**

Source: author calculation. *This is not the "real" overshoot difference for each company - which is zero - but the temperature difference translated into overshoot (based on Exhibit 12 – using TCRE=0.000545), so that we can compare the impact of the TCRE parameter with the other parameters.

These preliminary results show that some parameters have a greater influence than others on company temperature scores, in particular the denominator used to normalize emissions, intensity projection, and horizon. These results are consistent with Haalebos and Fouret (2022), who showed the significant impact of different company's emissions trajectories. On the other hand, the impact measured by varying the scopes is less significant in our study, but this is partly explained by the fact that the automotive sector studied by Haalebos and Fouret (2022) is more sensitive to scope 3 than the steel sector.

In a second phase, the sensitivity analysis based on this framework should therefore be extended to the analysis of deviations in ITR scores of different sectors and at portfolio level, enabling us to focus on the different aggregation options.

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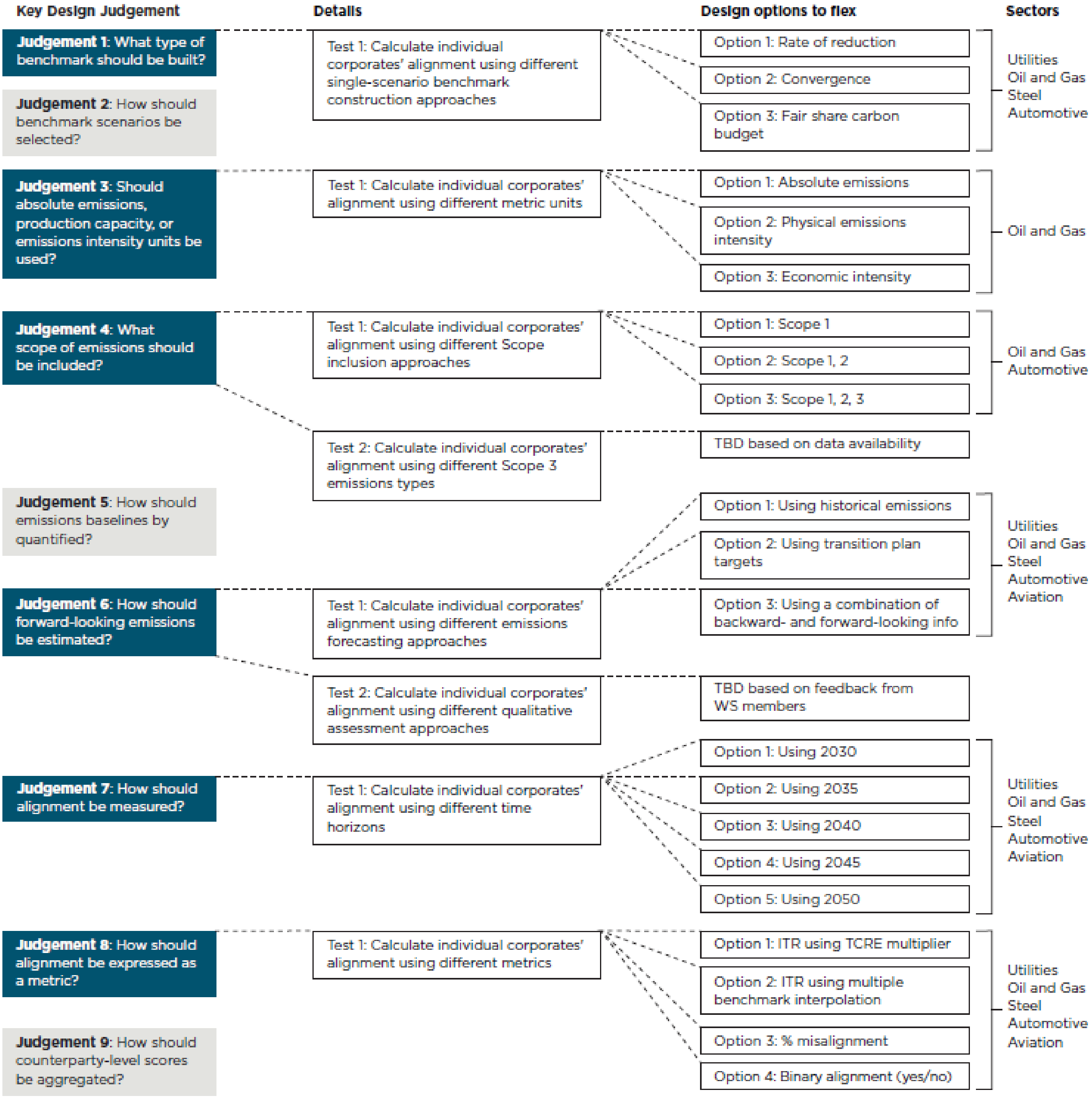
APPENDIX

6.1 Quantitative case study potential design options



Key Design Judgement	Details	Design options to flex	Sectors
Judgement 1: What type of benchmark should be built?	Test 1: Calculate individual corporates' alignment using different single-scenario benchmark construction approaches	Option 1: Rate of reduction	Utilities Oil and Gas Steel Automotive
		Option 2: Convergence	
		Option 3: Fair share carbon budget	
Judgement 2: How should benchmark scenarios be selected?			
Judgement 3: Should absolute emissions, production capacity, or emissions intensity units be used?	Test 1: Calculate individual corporates' alignment using different metric units	Option 1: Absolute emissions	Oil and Gas
		Option 2: Physical emissions intensity	
		Option 3: Economic intensity	
Judgement 4: What scope of emissions should be included?	Test 1: Calculate individual corporates' alignment using different Scope inclusion approaches	Option 1: Scope 1	Oil and Gas Automotive
		Option 2: Scope 1, 2	
		Option 3: Scope 1, 2, 3	
	Test 2: Calculate individual corporates' alignment using different Scope 3 emissions types	TBD based on data availability	
Judgement 5: How should emissions baselines by quantified?			
Judgement 6: How should forward-looking emissions be estimated?	Test 1: Calculate individual corporates' alignment using different emissions forecasting approaches	Option 1: Using historical emissions	Utilities Oil and Gas Steel Automotive Aviation
		Option 2: Using transition plan targets	
		Option 3: Using a combination of backward- and forward-looking info	
	Test 2: Calculate individual corporates' alignment using different qualitative assessment approaches	TBD based on feedback from WS members	
Judgement 7: How should alignment be measured?	Test 1: Calculate individual corporates' alignment using different time horizons	Option 1: Using 2030	Utilities Oil and Gas Steel Automotive Aviation
		Option 2: Using 2035	
		Option 3: Using 2040	
		Option 4: Using 2045	
		Option 5: Using 2050	
Judgement 8: How should alignment be expressed as a metric?	Test 1: Calculate individual corporates' alignment using different metrics	Option 1: ITR using TCRE multiplier	Utilities Oil and Gas Steel Automotive Aviation
		Option 2: ITR using multiple benchmark interpolation	
		Option 3: % misalignment	
		Option 4: Binary alignment (yes/no)	
Judgement 9: How should counterparty-level scores be aggregated?			

■ Prioritized for quantitative case studies ▨ Not currently prioritized for quantitative case studies

Source: GFANZ (2022b), Appendix 2, p.19

6.2 Model parameters

Exhibit 16: Impact of allocation, metric and market share growth treatment parameters on decarbonization benchmark and trajectory construction

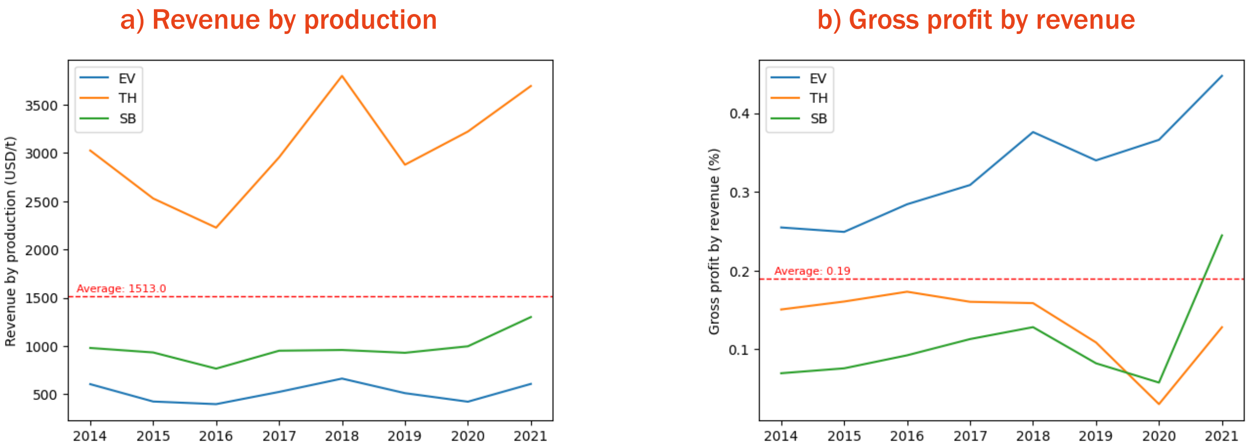
Allocation	Denominator	Growth treatment	Benchmark construction		Trajectory construction
			Benchmark intensity construction	Absolute benchmark emissions calculation	Absolute emissions calculation adjustment
Convergence	Intensity	Inorganic	Adjustment	Company denominator	Company denominator
		Organic	No adjustment	Company denominator following sector trend after reference year	Company denominator
		Neutral	No adjustment	Company denominator following sector trend after reference year	Company denominator following sector trend after reference year
Reduction	Intensity	Inorganic	Adjustment	Company denominator	Company denominator
		Organic	No adjustment	Company denominator following sector trend after reference year	Company denominator
		Neutral	No adjustment	Company denominator following sector trend after reference year	Company denominator following sector trend after reference year
	Absolute	organic	No adjustment	No need	Company denominator
Fair share	Intensity	inorganic	Adjustment (dynamic fair share)	No need	Company denominator
		organic	No adjustment (fair share based on first year)	No need	Company denominator

6.3 Scenario data management

Scenario data input for the model includes, for each sector s : revenue rev_{st}, gross profit (equivalent to the GDP) , production , and greenhouse gas emissions scope 1 $E1_{st}$, scope 2 $E2_{st}$, and scope 3 $E3_{st}$. The 2023 World Energy Outlook free dataset does not provide the variables rev_{st}, and $gross\_prof_{st}$, $E2_{st}$, $E3_{st}$ for the steel sector in the Net-Zero Emissions by 2050 scenario (NZE). We explain below how we estimated these variables.

We use the average historical revenue per unit of production of the three companies (1513 USD/t, Exhibit 17 a, c) as a multiplicative factor to estimate rev_{st} from $prod_{st}$. We use the average historical gross profit per revenue of the three companies as a multiplicative factor to estimate $gross\_prof_{st}$ from rev_{st} (19%, Exhibit 17 b, c).

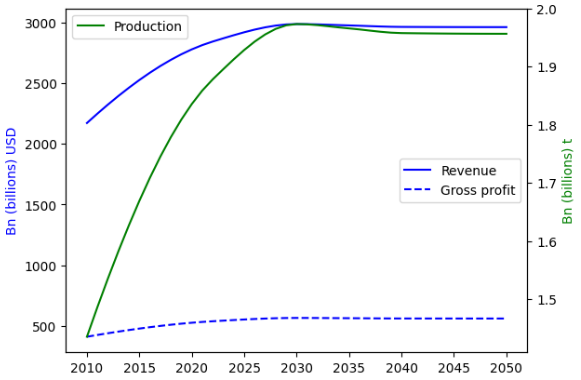
Exibit 17: Scenario data estimation for sector revenue and gross profit



a) Revenue by production

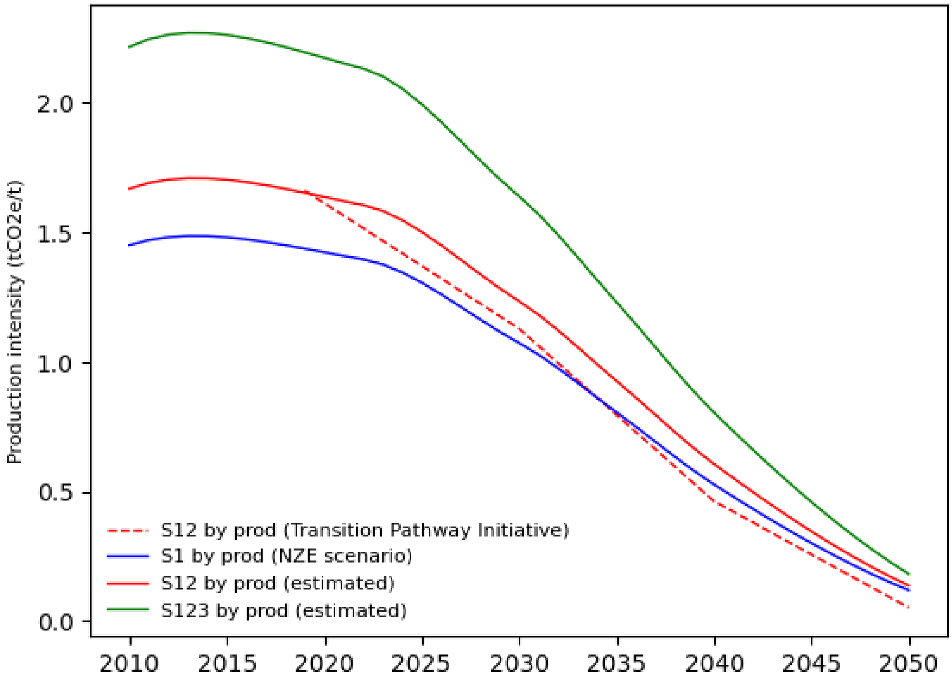
b) Gross profit by revenue

c) Estimated scenario data for the steel sector



For $E2_{st}$, we first tried to use the scope 1+2 production intensity of the Transition Pathway Initiative scenario, but the projected values after 2035 were lower than the scope 1 intensity of the NZE 2023 scenario (Exhibit 18). To remain consistent with this reference scenario, we estimated a scope 2 / scope 1 ratio (of 15%) so that the sector's scope 1+2 intensity would be equal with the Transition Pathway Initiative scenario values in 2020. We then applied this ratio to estimate $E2_{st}$ from $E1_{st}$ to 2050. We use the average historical ratio scope 3 emissions per scope 1 emissions of the three companies as a multiplicative factor to estimate $E3_{st}$, from $E1_{st}$ (38%, Exhibit 13 b, Exhibit 18).

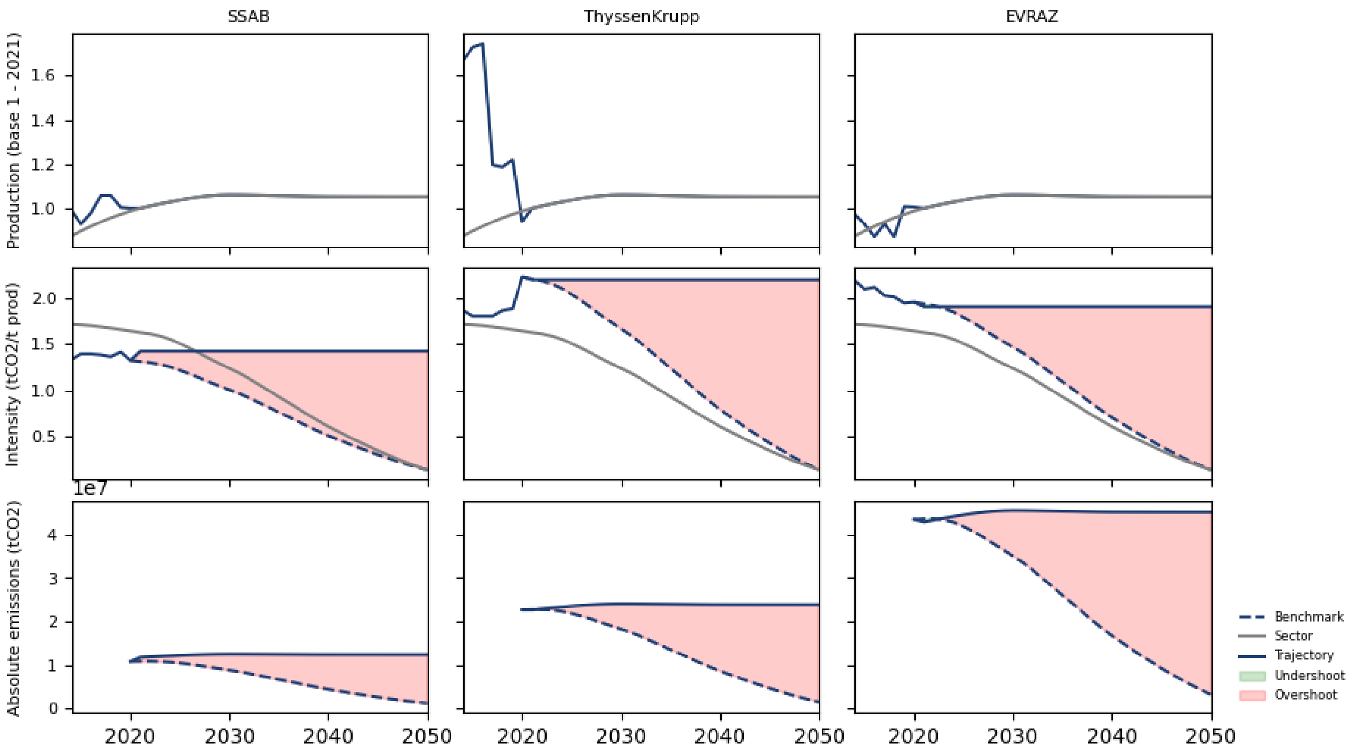
Exhibit 18: Scenario data estimation for sector scope 2 and scope 3 emissions



6.4 Detailed impact of each parameter

Exhibit 19: Impact on overshoot of different reference years

a) Reference year 2020

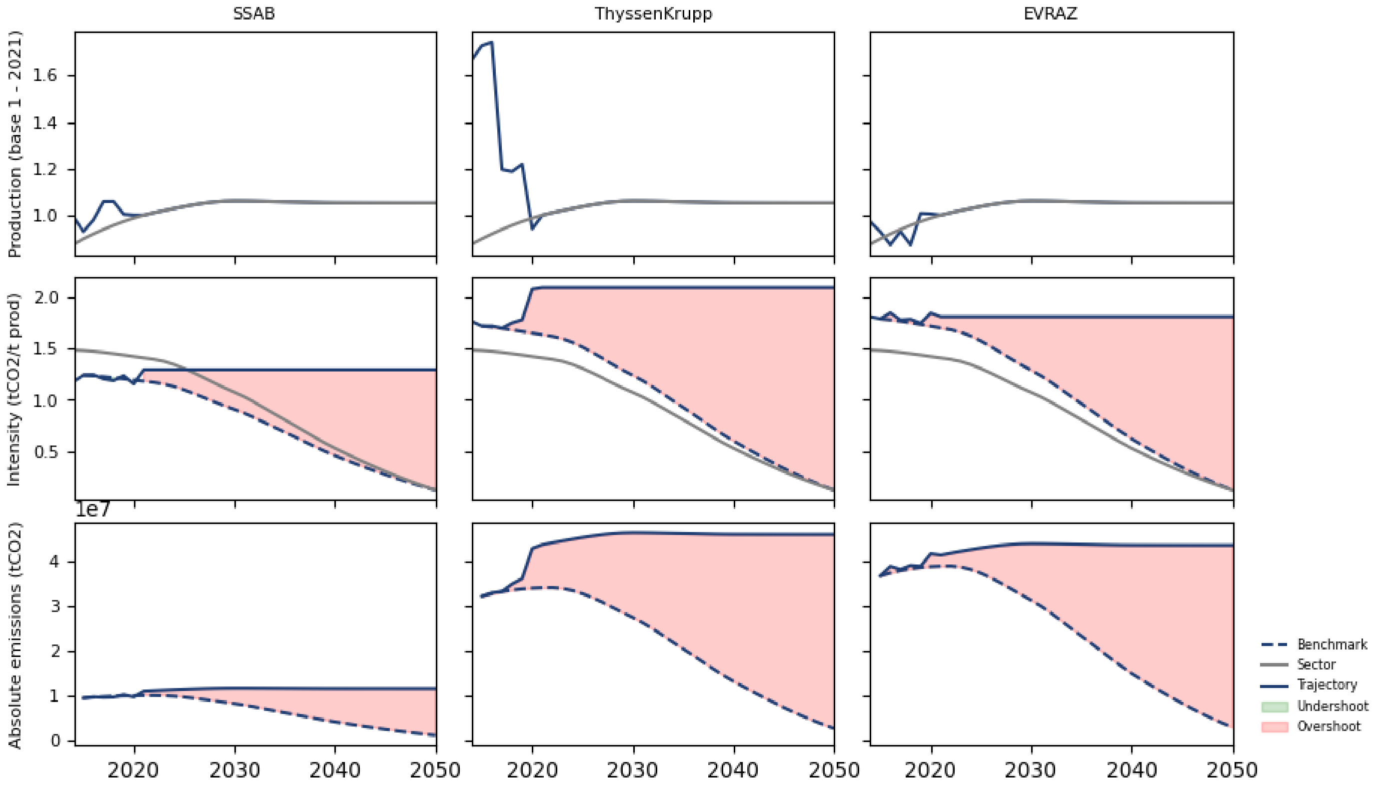


	SSAB	ThyssenKrupp	EVRAZ
Overshoot ref (Ref. year=2015)	69.2%	101.7%	56.6%
ITR ref (Ref. year=2015) 1.69°C		1.78°C	1.66°C
Overshoot (Ref. year=2020)	89.2%	80.4%	76.9%
ITR (Ref. year=2020)	1.75°C	1.72°C	1.72°C
Overshoot variation (Ref. year)	**+20.0%**	**-21.4%**	**+20.3%**

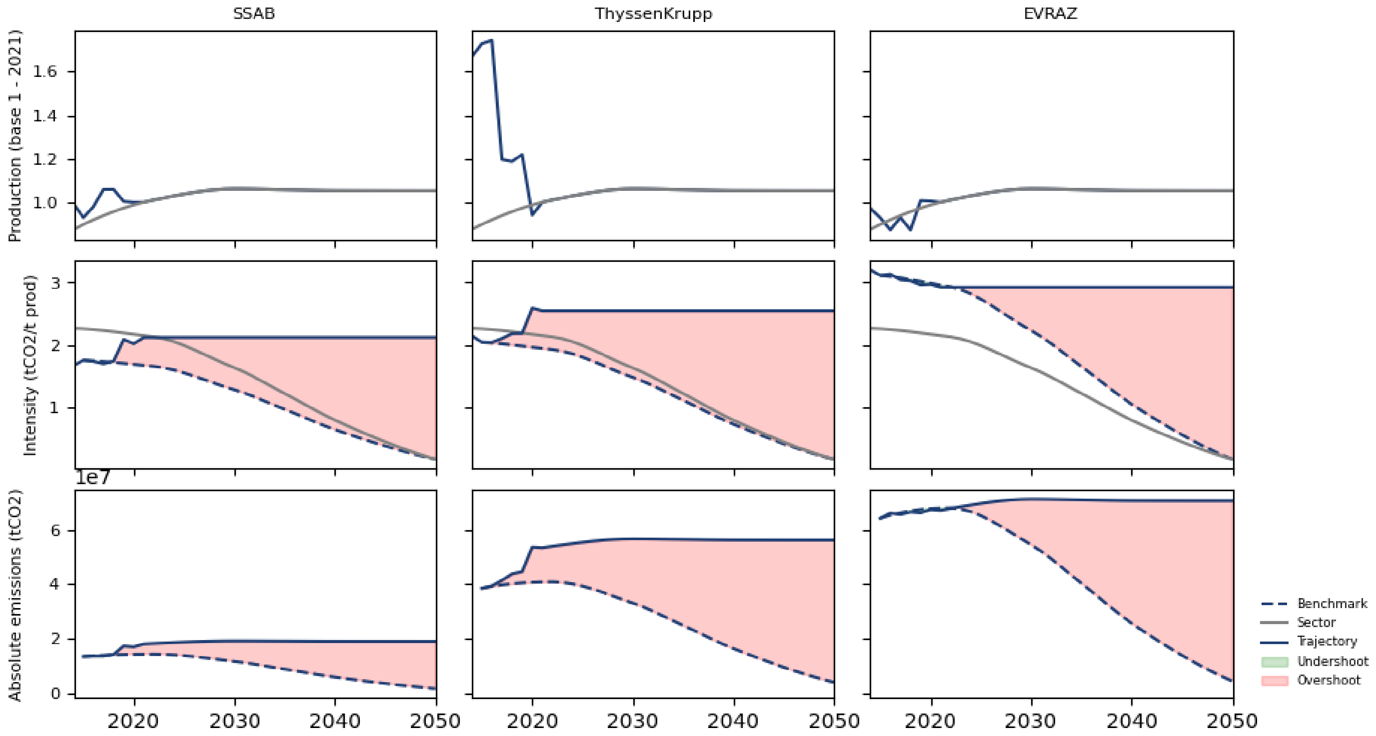
Source: author calculation.

Exhibit 20: Impact on overshoot of different scopes

a) Scope 1 only



b) Scope 123

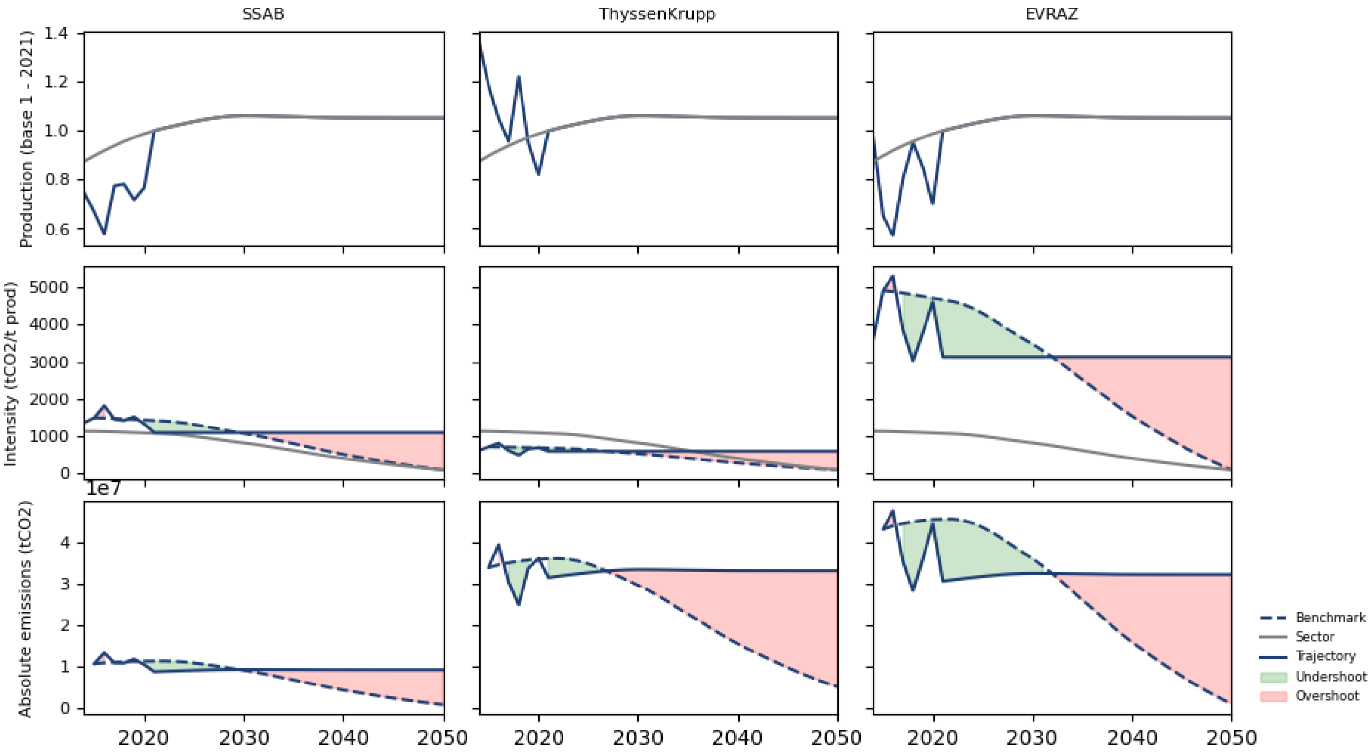


	SSAB	ThyssenKrupp	EVRAZ
Overshoot ref (Scope=relevant)	69.2%	101.7%	56.6%
ITR ref (Scope=relevant)	1.69°C	1.78°C	1.66°C
Overshoot (Scope=1)	72.2%	102.9%	72.3%
ITR (Scope=1)	1.7°C	1.79°C	1.7°C
Overshoot (Scope=123)	96.1%	104.3%	62.0%
ITR (Scope=123)	1.77°C	1.79°C	1.67°C
Maximum overshoot variation (Scope)	+ 26.9%	+ 2.7%	+ 15.8%

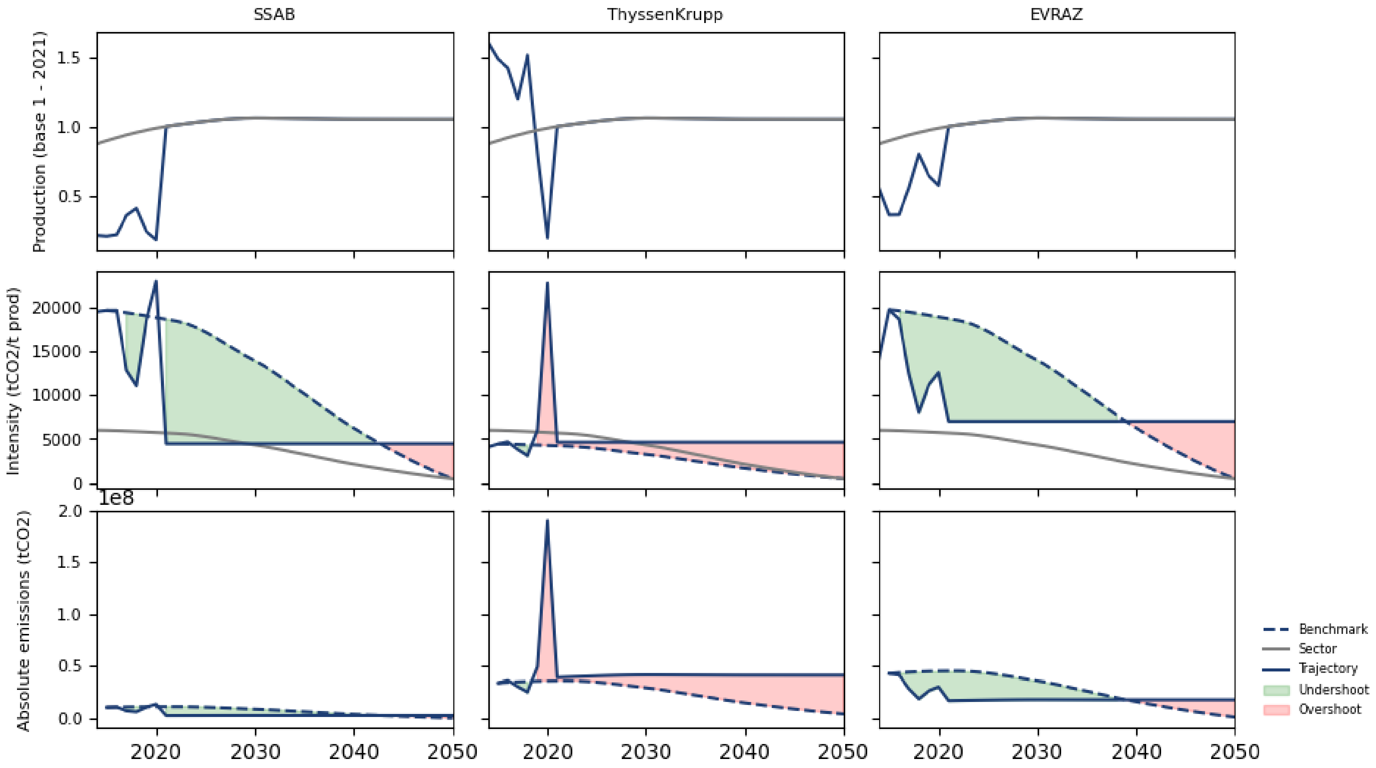
Source: author calculation.

Exhibit 21: Impact on overshoot of different denominators

a) Revenue



b) Gross profit

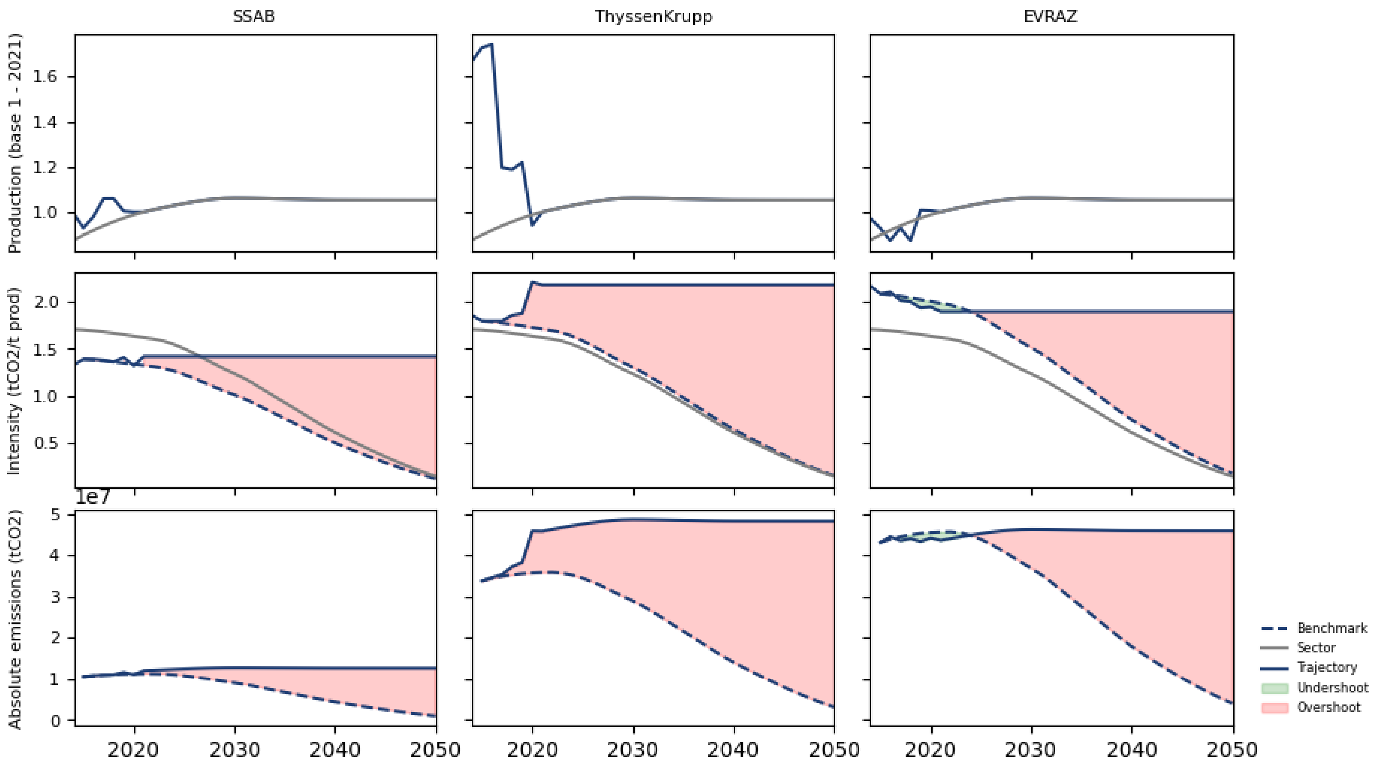


	SSAB	ThyssenKrupp	EVRAZ
Overshoot ref (Denominator=prod)	69.2%	101.7%	56.6%
ITR ref (Denominator =prod)	1.69°C	1.78°C	1.66°C
Overshoot (Denominator =rev)	32.7%	38.1%	18.7%
ITR (Denominator =rev)	1.59°C	1.61°C	1.55°C
Overshoot (Denominator =gross_prof)	-42.2%	89.6%	-28.5%
ITR (Denominator =gross_prof)	1.38°C	1.75°C	1.42°C
Overshoot variation (Denominator)	**-111.4%**	**-63.6%**	**-85.1%**

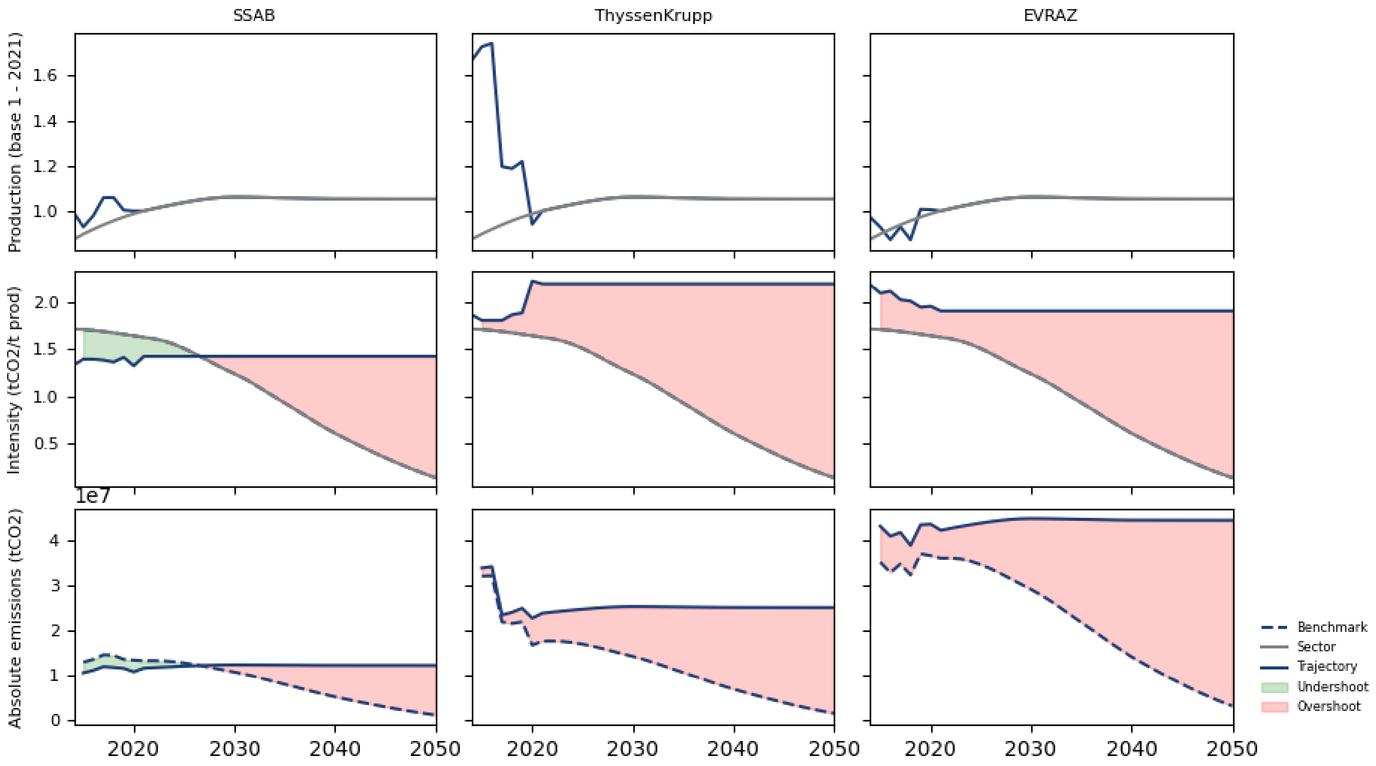
Source: author calculation.

Exhibit 22: Impact on overshoot of different allocation approaches

a) Reduction



b) Fair share

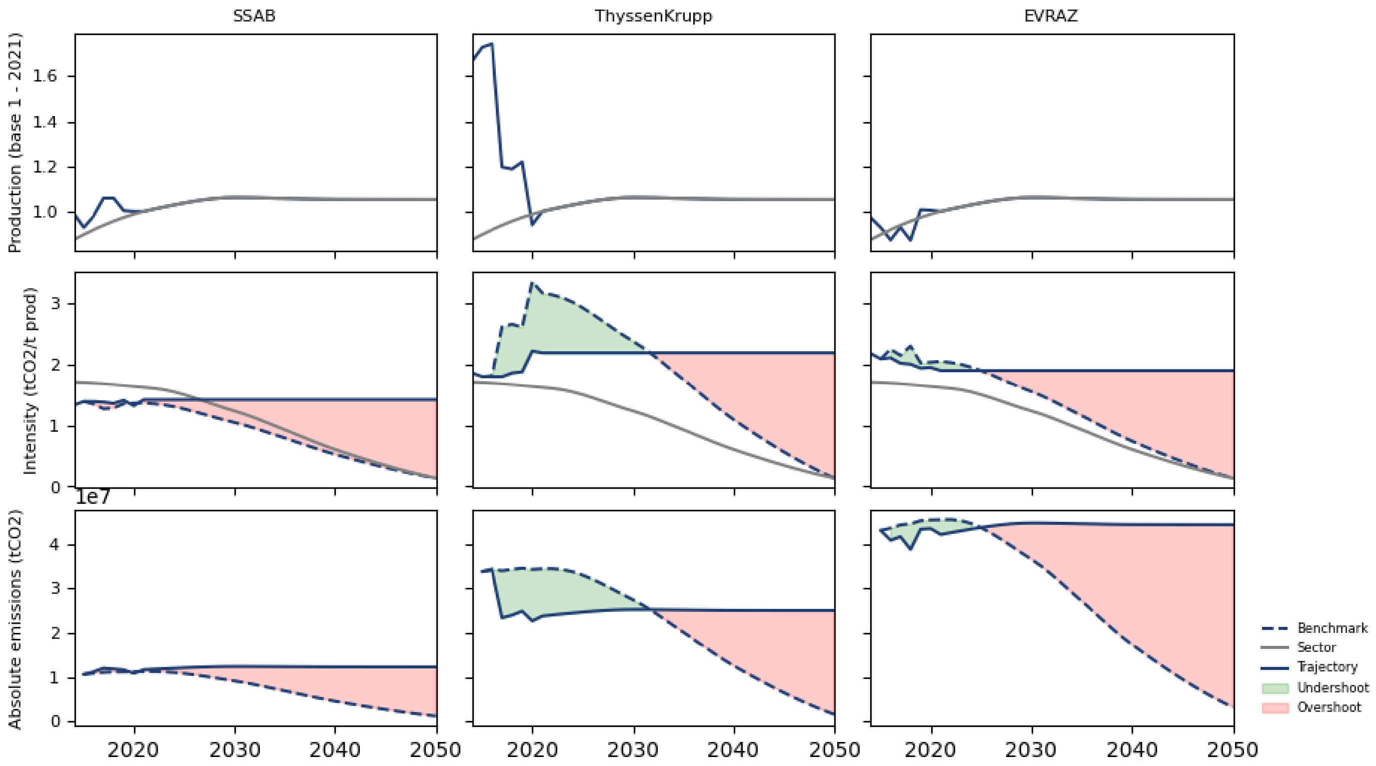


	SSAB	ThyssenKrupp	EVRAZ
Overshoot ref (Allocation=convergence)	69.2%	101.7%	56.6%
ITR ref (Allocation=convergence)	1.69°C	1.78°C	1.66°C
Overshoot (Allocation=reduction)	71.5%	101.1%	54.8%
ITR (Allocation=reduction)	1.7°C	1.78°C	1.65°C
Overshoot (Allocation=fair share)	39.0%	102.3%	90.1%
ITR (Allocation=fair share)	1.61°C	1.79°C	1.75°C
Overshoot variation (Allocation)	**-32.5%**	**+1.3%**	**+35.3%**

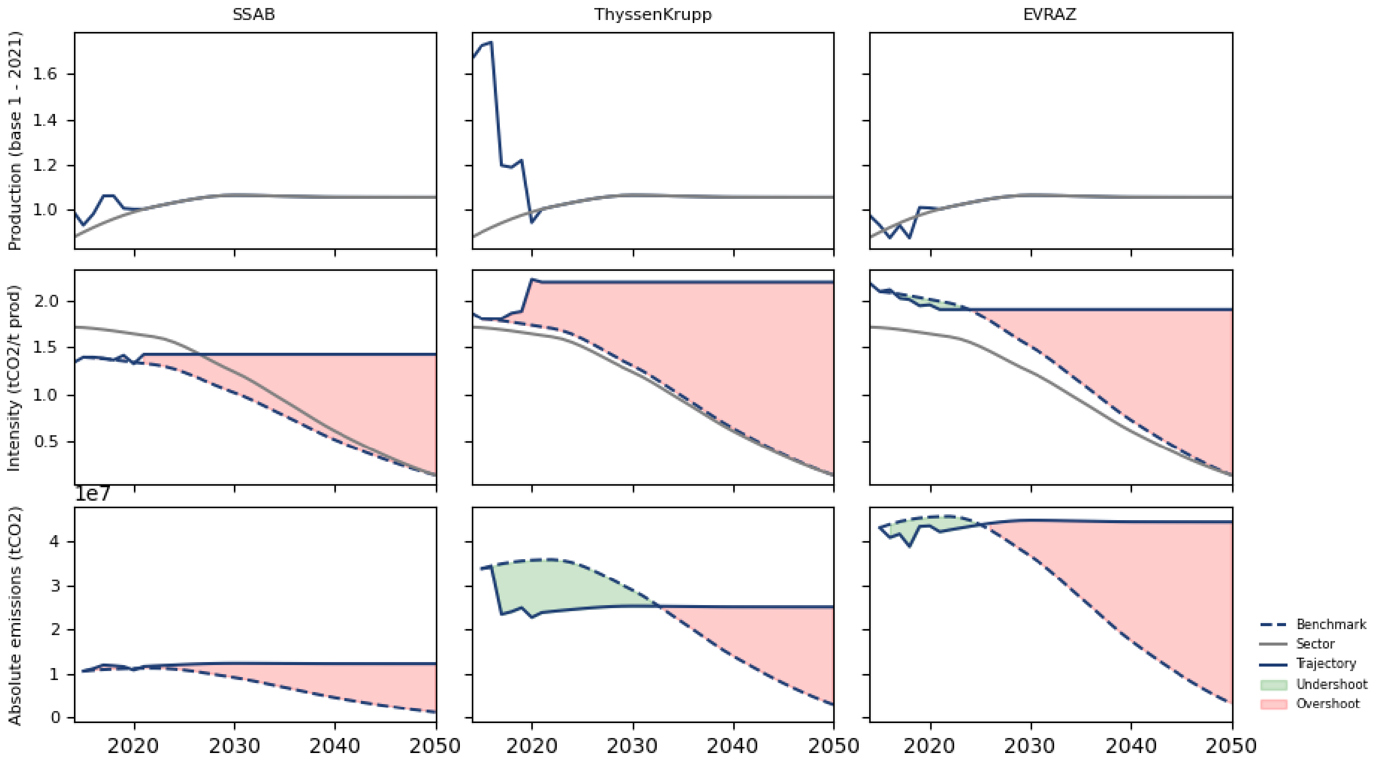
Source: author calculation.

Exhibit 23: Impact on overshoot of different company growth treatments

a) Inorganic



b) Organic

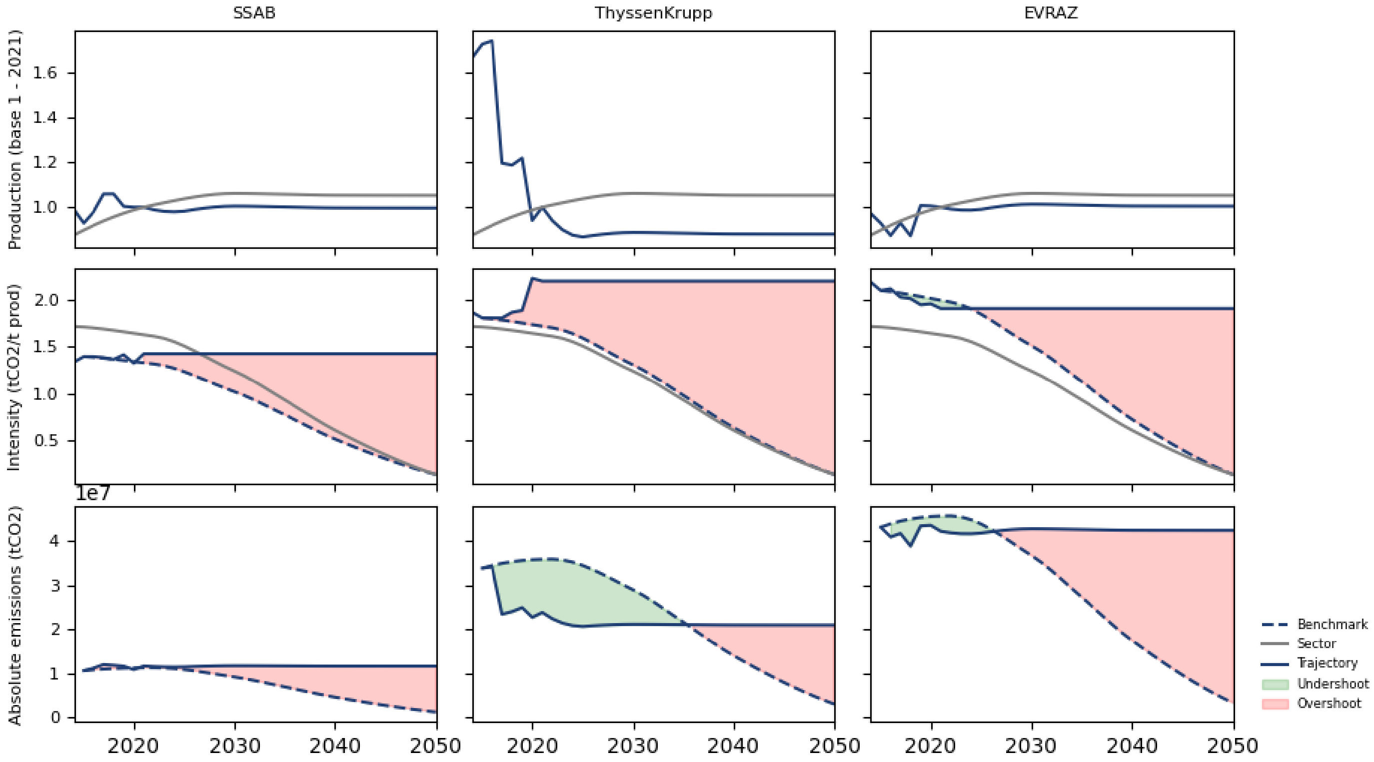


	SSAB	ThyssenKrupp	EVRAZ
Overshoot ref (Market share growth treatment=neutral)	69.2%	101.7%	56.6%
ITR ref (Market share growth treatment=neutral)	1.69 °C	1.78 °C	1.66 °C
Overshoot (Market share growth treatment=inorganic)	65.7%	17.1%	51.7%
ITR (Market share growth treatment=inorganic)	1.68 °C	1.55 °C	1.64 °C
Overshoot (Market share growth treatment=organic)	65.1%	10.4%	51.1%
ITR (Market share growth treatment=organic)	1.68 °C	1.53 °C	1.64 °C
Overshoot variation (Market share growth treatment)	**-4.2%**	**-91.3%**	**-5.5%**

Source: author calculation.

Exhibit 24: Impact on overshoot of different market-share projections

a) Historical

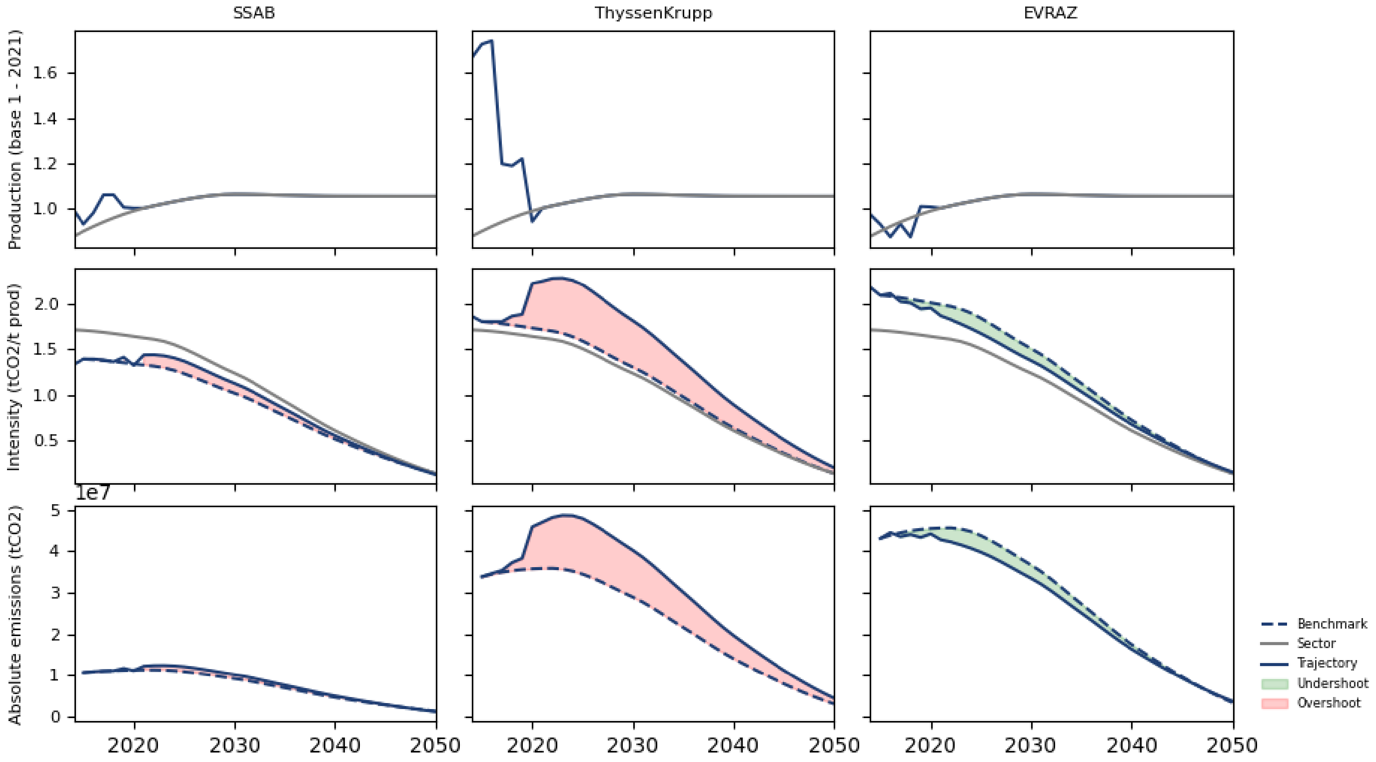


	SSAB	ThyssenKrupp	EVRAZ
Overshoot ref (Market share projection=constant)*	65.1%	10.4%	51.1%
ITR ref (Market share projection=constant)*	1.68°C	1.53°C	1.64°C
Overshoot (Market share projection=historical)	58.1%	-3.6%	45.7%
ITR (Market share projection=historical)	1.66°C	1.49°C	1.63°C
Overshoot variation (Market share projection)	**-7.0%**	**-13.9%**	**-5.4%**

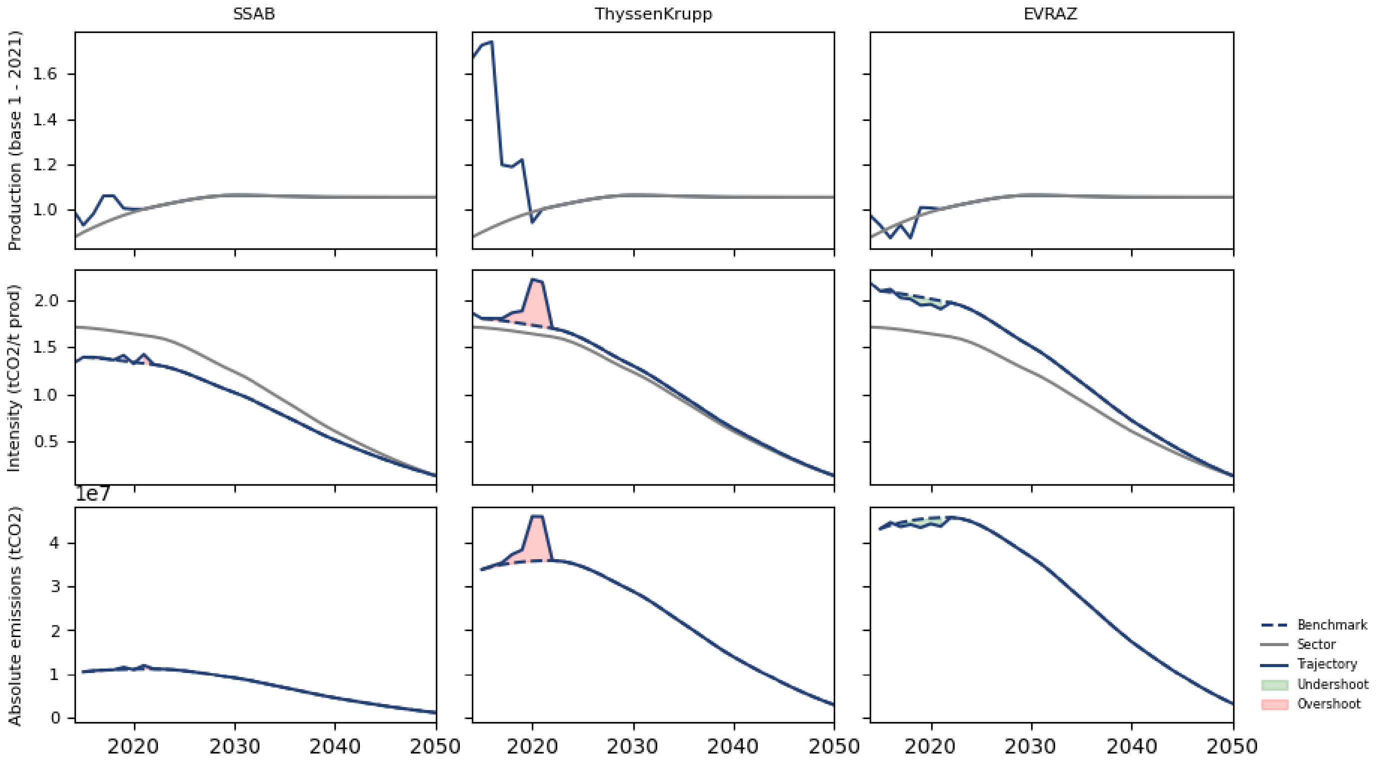
Source: author calculation. *This reference configuration is set with growth treatment parameter equal to “organic”.

Exhibit 25: Impact on overshoot of different intensity projections

a) Historical



b) Based on targets



	SSAB	ThyssenKrupp	EVRAZ
Overshoot ref (Intensity projection=constant)	69.2%	101.7%	56.6%
ITR ref (Intensity projection=constant)	1.69°C	1.78°C	1.66°C
Overshoot (Intensity projection=historical)	7.0%	30.7%	-6.1%
ITR (Intensity projection=historical)	1.52°C	1.59°C	1.48°C
Overshoot (Intensity projection=targets)	0.5%	3.1%	-0.7%
ITR (Intensity projection=targets)	1.5°C	1.51°C	1.5°C
Overshoot variation (Intensity projection)	**-68.73%**	**-98.63%**	**-62.65%**

Source: author calculation.

Exhibit 26: Impact on ITR of different TCRE

	SSAB	ThyssenKrupp	EVRAZ
Overshoot ref (TCRE value=0.000545)	69.2%	101.7%	56.6%
ITR ref (TCRE value=0.000545)	1.69°C	1.78°C	1.66°C
ITR (TCRE value=0.00027)	1.60°C	1.64°C	1.58°C
ITR (TCRE value=0.00063)	1.72°C	1.83°C	1.68°C
Overshoot variation (TCRE value)*	**-32.2*%**	**-50.1*%**	**-28.6*%**

Source: author calculation. *This is not the “real” overshoot deviation for each company - which is zero - but the temperature deviation translated into overshoot (based on Exhibit 12 – using TCRE=0.000545), so that we can compare the impact of the TCRE parameter with the other parameters.

Exhibit 27: Impact on ITR of different ITR time management options

	SSAB	ThyssenKrupp	EVRAZ
Overshoot ref (ITR time management=budget)	69.2%	101.7%	56.6%
ITR ref (ITR time management=budget)	1.69°C	1.78°C	1.66°C
ITR (ITR time management=pathway)	1.63°C	1.72°C	1.60°C
Overshoot variation (ITR time management)*	**-21.5*%**	**-21.5*%**	**-21.5*%**

Source: author calculation. *This is not the “real” overshoot deviation for each company - which is zero - but the temperature deviation translated into overshoot (based on Exhibit 12– using TCRE=0.000545), so that we can compare the impact of the ITR time management parameter with the other parameters.