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Assessing the greenhouse gas emission reduction potential of companies with net-zero emission commitments

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As the consequences of decades of extensive anthropological carbon emissions are slowly becoming apparent in our everyday lives, curbing emissions is essential in keeping our planet habitable. I have been sceptical towards the emission mitigation efforts of companies and saw this topic as a great opportunity to (in)validate my scepticism.

I would like to express my gratitude to my primary supervisor, Prof. Dr Niklas Höhne, who introduced me to the topic and guided me throughout this project. His inexhaustible positivity, his trust and his ability to make me reflect on complex matters in a light-hearted, yet constructive, fashion have solved many of my doubts and headaches. Thank you for sharing your insights and our many fruitful discussions, you are a true inspiration!

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Abbreviation	Definition
CAAT	Climate Action Aggregation Tool
CAT	Climate Action Tracker
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CDP	Carbon Disclosure Project
CO2	Carbon dioxide
CO2-eq	Carbon dioxide equivalent - measure to compare various greenhouse gases in terms of their global-warming potential
CPPs	Current policy projections
DACCS	Direct air capture with carbon storage
DDL	Data Driven Enviro Lab
EAC	Energy attribute certificate
EU ETS	European Union Emissions Trading System
FIT	Feed-in tariffs
GHG	Greenhouse gas emissions
Gt	Gigatonne
ICAT	Initiative for Climate Action Transparency
kg	Kilogram
kt	Kilotonne
Mt	Megatonne
MWh	Megawatt-hour
n	Number of companies
NAZCA	Non-state Actor Zone for Climate Action
NDC	Nationally Determined Contributions
NSA	Non-state actors
PPA	Power purchase agreement
RE	Renewable energy
REC	Renewable energy certificate
RE-E	Renewable electricity
(RE)GO	(Renewable Energy) Guarantee of origin
SBTi	Science Based Targets initiative
Scope 1	Direct GHG emissions occurring from facilities and vehicles controlled by the company
Scope 2	GHG emissions resulting from the generation of electricity, steam, heating and cooling consumed by the company
Scope 3	Indirect emissions in the value chain, both upstream (suppliers) and downstream (clients)
t	Tonne (1000 kg)
TS	Technological sequestration
UNFCC	United Nations Framework Convention on Climate Change
UNGC	United Nations Global Compact
UNOPS	United Nations Office for Project Services
WRI	World Resources Institute
WWF	Wide Fund for Nature

Abstract

My study analysed publicly available data about companies' greenhouse gas emissions and climate-action strategies to assess the reduction potential of their emission-reduction targets. Forty-two companies with ambitious commitments to reduce emissions to net-zero were qualitatively and quantitatively assessed.

My quality-assessment template consisted of 35 indicators and lists companies' base-year emissions, reduction targets and mitigation strategies. An impact model was developed to quantify the most realistic reduction potential by assuming the effectiveness of emission-reduction methods outside the scope of the companies' own operations. The resulting dataset, that included base-year emissions and realistic reduction targets, was compared with a dataset where the companies' net-zero commitments were taken at face value. My impact assessment showed that mitigation strategies to achieve net-zero commitments differ among sectors. Energy and telecom companies focus on own emissions, while companies in the transport, fossil fuels and finance industry to a larger extent resort to market-based measures.

Transparency about the amount and type of external reduction methods utilised in each mitigation strategy is required to assess the quality of commitments. To improve the reduction potential of net-zero commitments, external reduction methods should be of high quality and only be used to address emissions that currently cannot be addressed by the company itself. The determination of these residual emissions and the utilised methods to reduce them should be reviewed iteratively. High quality external reduction methods are verifiable, correctly accounted for and have a low risk of non- additionality, reversal, and creating negative unintended consequences.

I showed that the analysed companies' combined annual emissions currently have the potential to reduce from 881 to 350 megatonnes of greenhouse gas emissions in 2050. This is a 60% reduction compared to 2019, although a 100% reduction is claimed. The use of external reduction methods considerably reduced the realistic emission-reduction potential of these net-zero commitments, to the extent that the dataset's emission trajectory is not aligned with the emission-mitigation pathway limiting global warming to 1.5°C.

1. Introduction

Background information

The impacts of anthropogenic greenhouse gas emissions are becoming more apparent by the day and are broadly acknowledged by the academic world. As of February 2021, 191 Member States of the United Nations Framework Convention on Climate Change (UNFCCC) have ratified the Paris Agreement. Although there is no mechanism or legal ground to force a country to set a specific emission target by a specific date, “parties aim to reach global peaking of greenhouse gas emissions as soon as possible” (UNFCC, 2015). Member states need to reduce greenhouse gas emissions to reach the Agreement’s target of holding the increase in global average temperature well below 2°C and pushing for 1.5°C. Post-2020 climate actions are articulated in the Nationally Determined Contributions (NDCs). An NDC should reflect the members’ responsibilities and capabilities to reduce national GHG emissions.

The NDCs set higher targets than policies that are currently enforced but their current aggregated impact will nonetheless lead to a median warming of 2.6°C to 3.1°C by the year 2100 (Rogelj et al., 2016). To reach the Agreement’s target, NDCs must therefore become more ambitious. Further, substantial efforts are required from non-state actors (NSAs), which comprise regions, cities and companies. NSAs have an important role to play in building confidence in governments concerning climate policy by providing space for experimentation and coordinating policy implementation. Climate action commitments and data transparency support the improvement of national goals and sectoral transformations to decarbonise society (NewClimate Institute et al., 2019). Thus far however, additional emission reduction contributions made by NSAs are comparatively small to what member states have already pledged in their NDCs (Hsu et al., 2018).

Due to the transnational and profit-maximising character of most companies, their pledged climate action should be monitored closely. I think companies should be held to the same standards in reducing emissions as the NDCs of countries wherein they operate. The development of ambitious emission reduction targets is a first step in climate action. Participants of the Race to Zero Campaign, set up by the UNFCCC, exemplify such ambition by committing themselves to net-zero emissions in or before 2050 (UNFCCC, 2020b).

An entity achieves net-zero by removing as much GHG emissions from the atmosphere as it emits (IPCC, 2018). Net-zero emission commitments thus still allow for GHG emissions, but these remaining emissions are to be compensated for by removing emissions from the atmosphere elsewhere. The amount and method of reducing and removing emissions need to be monitored, reported, and evaluated to determine the expected impact. A uniform method to measure emissions promotes the ability to track performance among organisations, sectors and regions.

The most widely adopted corporate accounting and reporting standard for emissions is the Greenhouse Gas Protocol, developed through a collaboration between the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). The protocol divides activities into three categories; Scope 1, Scope 2 and Scope 3. Scope 1 comprises direct GHG emissions occurring from facilities and vehicles controlled by the company. Scope 2 emissions account for GHG emissions resulting from the generation of electricity, steam, heating and cooling consumed by the company (Sotos, 2015). Indirect emissions in the value chain, both upstream (suppliers) and downstream (clients), are considered in Scope 3 (Kachi et al., 2020). Examples of the last category include the emissions resulting from extraction and production of purchased materials or transportation of goods and personnel (Ranganathan et al., 2015).

A distinction should be made between the emissions that a company plans to reduce itself, and the emissions that are removed from the atmosphere or reduced elsewhere. Quantifying reductions of own emissions is often relatively straightforward, as efficiency improvements and reduction of material use are easily defined. Emission mitigation outside the direct activities of the company is more complicated to assess. The reported Scope 2 emission reductions by improving one's electricity procurement are an example of this.

A company can purchase renewable electricity (RE-E) via a power purchase agreement (PPA). With a PPA, a company enters a multiple-year contract with an RE-E provider and commits to purchase a specific amount of electricity at a predetermined price (IRENA, 2018). For every purchased megawatt-hour (MWh) of electricity, the company receives an energy attribute certificate (EAC). An EAC represents the exclusive rights to the attributes of this one MWh of RE-E (IRENA, 2018). Several types of these certificates exist, among which the guarantees of origin (GOs) in Europe and renewable energy certificates (RECs) in the United States, but all are based on the same principle. EACs can also be attained without committing to a long-term contract, these certificates are referred to as unbundled EACs. The caveat of EACs is that it is difficult to determine how much RE-E would be produced without them, especially since prices and sources vary considerably.

The incremental capacity of RE-E that is generated by purchasing EACs is called 'additionality' (IRENA, 2018). Oversupply and associated low prices are strong indicators that the additionality of unbundled EACs is low (Mulder & Zomer, 2016). EACs attained from PPAs have a higher additionality (NewClimate Institute & Data-Driven EnviroLab, 2020). EACs are legal instruments and are considered an external mitigation method, compensating rather than reducing own emissions. The GHG protocol prescribes two accounting methods for Scope 2 emissions. The location-based method reflects the average emissions intensity of the utilised energy grid, while the market-based method reflects emissions from electricity that companies have purposefully chosen (Sotos, 2015). Legal instruments can only be used in the market-based accounting method.

Carbon offsets are another mitigation method for companies. Unlike the options to improve electricity procurement, offsets can address emissions in all three scopes under the Greenhouse Gas Protocol. Offsets offer global emission reductions through additional, external projects. The verification of such projects allows a company to subtract the reduced emissions elsewhere from its own organisational emissions (EPA, 2018). Unlike EACs, offsets cannot be directly subtracted from emissions accounted for under the GHG protocol. Instead, they compensate for these reported emissions afterwards.

Offsetting has faced increased scrutiny since the introduction of the Paris Agreement. NDCs should reflect countries' ambitious emission-reduction targets for each of their economic sectors. Countries that sell of emission reductions to foreign investors in the form of offsets therefore complicate achieving their national targets. Otherwise, offsets pose the risk of double counting emission reductions that would have taken place regardless of their purchase. Offsets can also incentivise countries to set less ambitious targets or distract buyers from reducing own emissions. For some, offsets may even serve as a justification for inaction (Kachi et al., 2020).

Net-zero emission commitments by companies are a relatively new concept. Insight in the impacts that these commitments can achieve, is missing. Earlier research by Kuramochi et al. (2020) quantified the net aggregate impact of commitments by individual NSAs in 2030. They assumed companies to fully implement their commitments, leaving quality considerations regarding the mitigation strategy out of account. Kachi et al. (2020) explored a number of reduction commitments and discussed what factors are important to consider when gauging ambitions. Their paper forms a starting point to understand commitment terminology and explains how emissions from different scopes are usually addressed and how this can be done otherwise. Implementation approaches of net-zero commitments were assessed on additionality by NewClimate Institute & Data-Driven EnviroLab (2020). This study helps to identify truly ambitious actors by assessing the characteristics of actors' mitigation strategies.

What is yet lacking is a quantitative assessment of the reduction potential of individual NSAs with net-zero commitments where quality considerations regarding implementation approaches are taken into account. My study confines itself to determining the quality and reduction potential of companies' net-zero commitments that are due in or before 2050.

Problem statement

A net-zero emission target can be understood by analysing the elements that it comprises. Which types of emissions are included? By how much does the actor plan to reduce its own emissions? And when does the actor plan to reach net-zero emissions?

In practice, information about the mitigation strategies to achieve net-zero commitments is scarce (Chan et al., 2018; Kuramochi et al., 2020). Transparency around mitigation strategies to achieve net-zero commitments varies widely and target terminology is used interchangeably due to a lack of standardisation (NewClimate Institute & Data-Driven EnviroLab, 2020). Data scarcity and lack of transparent reporting impede tracking climate action progress of companies. A better understanding of progress is required to assess whether companies will fulfil their pledged contributions (Chan et al., 2018). Untransparent and inconsistent data on the implementation of companies' net-zero commitments also hinders governmental coordination and global cooperation.

Prior studies questioned the effectiveness of cheap external reduction methods (Michaelowa et al., 2019; NewClimate Institute & Data-Driven EnviroLab, 2020; Kachi et al., 2020). My study is the first to process these qualitative findings into a quantitative assessment. The calculation of a realistic reduction potential where the effectiveness of external reduction methods is taken into account is new and provides additional detail to prior research.

The ulterior motives of many companies and their modest climate contributions thus far make them an interesting subject for analysis. Considering the fractional data availability, a comprehensive overview of mitigation strategies by companies and other NSAs is lacking (Hsu et al., 2018). Companies' mitigation strategies need to be assembled and assessed on their quality to calculate the realistic reduction potential of current net-zero commitments.

Purpose of the study

My study aims to make a quality assessment and an impact assessment of net-zero emission commitments by companies. The focus on individual companies creates an overview of utilised strategies and enables a comparison between sectors. The emission reduction potential of net-zero commitments is assessed to understand the extent to which these commitments actively support a transition towards deep decarbonisation. Such an understanding tells whether commitments need to be supported with additional regulations. This study is guided by the following research questions (RQs):

RQ1 What is the quality of current net-zero emission commitments by companies considering their target definition and mitigation strategies?

RQ2 What is the emission reduction potential of net-zero emission commitments by companies considering their quality? This requires data aggregation and the formulation of a baseline scenario.

Outline

The report starts with describing how companies are selected and on what characteristics their mitigation strategies are assessed. A detailed description of the identified external reduction methods substantiates their assumed effectiveness, which helps in understanding why this assessment primarily focusses on these methods. The methodology chapter also describes how information about the use and effectiveness of external reduction methods is used to develop and interpret the impact assessment.

The results chapter first describes the outcomes of the quality assessment. Companies are compared on individual and sectoral level to make the reader understand the observed differences before zooming out and describing the overall emission trajectory in the impact assessment. Findings are extrapolated to assess the reduction potential of all companies with net-zero commitments. At the end of the results chapter, the impact model's sensitivity and extrapolation's significance are tested. Alternatives for influential input parameter assumptions are also considered.

The discussion then explains the meaning and value of these research findings and puts them into wider context. After the study's design choices are critically reflected upon, the outcomes are interpreted in the conclusions and linked back to both RQs. The gathered insights show where the reduction potential of net-zero commitments can be improved. The fossil fuels industry for example, turns out to be untransparent about its use of external reduction methods and their realistic emission reductions are expected to be less than half of what they claim.

2. Methodology

My assessment process to determine the realistic reduction potential of net-zero emission commitments is presented in Figure 1. Rectangles represent a set of operations, rhomboids indicate input data, while cylinders represent databases.

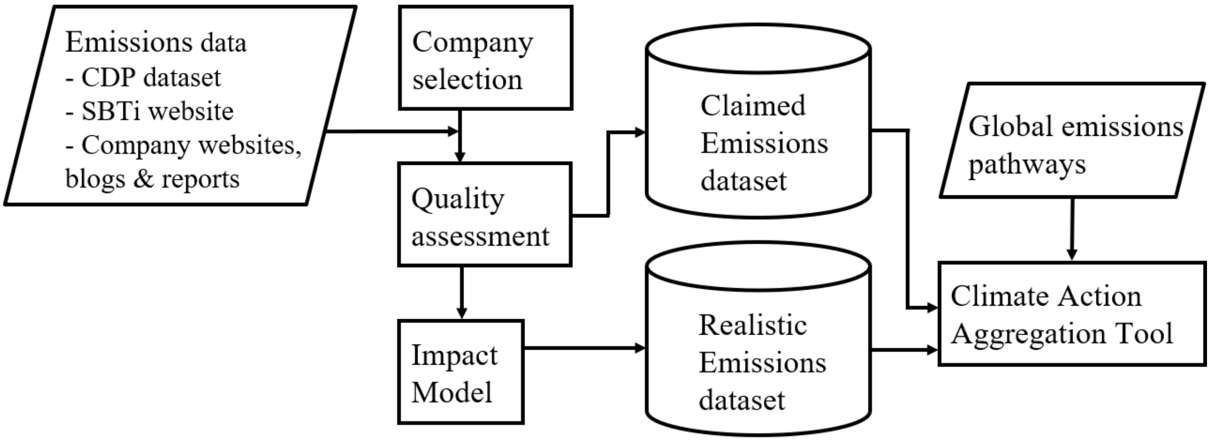

Figure 1 – Overview diagram of the assessment process in this study

Emissions data from selected companies with net-zero commitments is gathered in the quality assessment, which answers RQ1. CDP and SBTi are both initiatives for companies to report emissions and reduction targets, their workings and definitions will be explained later in this chapter.

Claimed Emissions: Emissions and targets reported in the quality assessment are taken at face value in the Claimed Emissions dataset, the use of external reduction methods is not evaluated.

Realistic Emissions: The data from the quality assessment is also consulted for the Realistic Emissions dataset. However, this data is recalculated by the Impact model which makes assumptions about the effectiveness of external emission reduction methods. As I consider offsets and certain forms of renewable energy (RE) procurement to have a lower impact on emissions than what companies claim, the potential of emission targets often diminishes after reviewing the reduction strategy.

An aggregation tool compares the two datasets and develops their emission trajectories based on the provided emissions and absolute reduction targets. By importing emission pathways from the Climate Action Tracker (CAT)[1], the emission trajectories of the datasets can be compared to several policy scenarios. The observed differences between the datasets and policy scenarios help in answering RQ2.

2.1. Company selection

Emissions data is collected in two separate phases of assessment. The first phase of data collection is explorative. I analyse reputable companies that appear to pioneer in climate efforts in their respective industries and provide extensive information on their net-zero emissions

[1] Climate Analytics and New Climate Institute. (n.d.). The Climate Action Tracker. Retrieved 24 February 2021, from https://climateactiontracker.org/global/temperatures/

progress. The companies have been selected in consultation with NewClimate Institute for pioneering in climate efforts in their industries. Apart from contributing to a research paper, the gained experience from the explorative phase allows for small adjustments in the quality criteria and method of data gathering.

In the second phase, a sample is taken from a comprehensive dataset of companies with net-zero emission commitments. This dataset was prepared by the Data Driven Enviro Lab (DDL) and incorporates data that was voluntarily supplied by companies to the Carbon Disclosure Project (CDP) and Non-state Actor Zone for Climate Action (NAZCA). The dataset was supplemented with information about emissions and ambitions which were scraped from the internet (NewClimate Institute & Data-Driven EnviroLab, 2020). Access to the dataset requires a licence, which was obtained by NewClimate Institute and extended to me. Only aggregate values derived from the dataset are mentioned in this report, as the details are confidential (CDP allows only restricted use of their data).

Members of emission reduction initiatives and companies with ambitious reduction targets are also included in the dataset. Modifications are made to remove duplicates and companies that are not listed as 'net-zero'; companies listed with either 1 or 'NA' in the 'net-zero' column remain. The remaining list of 1535 companies still includes some companies that have not made explicit net-zero emission commitments, but an adequate method to filter these companies out is lacking. The inclusion of such false positives is considered less harmful to the outcome of the study than the exclusion of false negatives, which are companies that do have net-zero commitments.

Time constraints prevent me from studying the whole set of 1535 companies. Companies are randomly selected from the list to be investigated. Explicit net-zero commitments and total Scope 1 and 2 emissions are determined through an online scan of environmental documents, blogs and websites. The findings, including false positives, are extrapolated to approximate the emission reduction potential of all companies with net-zero emission commitments. Quality and impact assessments are performed on the sample's net-zero committing companies.

2.2. Quality assessment

Companies' emissions, targets, and strategies depend on many factors, internally and externally. The size, activities and sector of a company influence the amount of emissions and what is reported. Net-zero commitments come in many shapes and sizes and are not directly comparable. A qualitative assessment is best suited to capture the details of companies' net-zero emission commitments. An assessment template is developed which guides data collection. The resulting comprehensive overview of individual efforts can be used for quantitative comparisons between companies and sectors afterwards.

A first set of indicators was developed by Silke Mooldijk and Thomas Day of NewClimate Institute to study the ambiguity of net-zero targets. The set of indicators, from here on referred to as the quality assessment, has been edited by me to make data collection more intuitive and allow for statistical analysis. The utilised template can be found in Appendix A. Answers to the quality assessment are processed in the respective Microsoft Excel sheet for each company.

Additional information that is not captured by the questions, such as graphs or thoughts are placed in the space underneath the indicators.

Data is collected in two separate forms. Standardised and short answers allow analysis in aggregate form. Details that can be used for case studies or providing context are reported in a separate column. Emissions data are retrieved from the DDL dataset and the Science Based Targets initiative (SBTi) website, but mostly from companies' websites, blogs and environmental reports. Some emissions and strategy data collected by Silke Mooldijk for other research purposes is reused in the quality assessment for this study.

2.2.1. Reduction strategies

The most elaborate section of the quality assessment focuses on mitigation approaches. Whether the company has a plan to achieve its target and how this plan was developed affects the certainty of achieving the commitment. It is also important to know which scopes are addressed by the company, and in what way.

The description and terminology of a net-zero commitment can make an important difference in the emission reductions that are to be expected. Companies use a range of commitment terms, and definitions slightly differ. All companies that aim to nullify or neutralise emissions are included in the analysis, but not all terms are considered equal. 'Carbon neutral' generally implies a higher reliance on external reduction methods than 'net-zero'. Reliance on such methods is also nearly imperative for reduction targets set to be reached within this decade. On the other hand, if no additional explanation or strategy is provided, net-zero targets scheduled for 2050 can be interpreted as postponing immediate action. All target terminologies are lumped under net-zero commitments in this study, unless stated otherwise.

A good strategy breaks its targeted emissions up in smaller portions and explains what reduction method is envisioned per portion. When portions of emissions are addressed at different moments in time, for example because the envisioned reduction technology is still in its infancy, this is indicated as well. A top-down approach by the board or the involvement multiple departments and stakeholders influence the mitigation strategy's success as well.

Apart from a net-zero commitment, a robust emission reduction strategy includes intermediate targets, as progress can be stimulated due to increased accountability. Intermediate targets can help in developing a chronological timeline of actions, which makes it easier to monitor performance. Intermediate targets can be expressed in absolute or specific reductions, the latter are also known as intensity targets. While absolute emission targets focus on the total quantity of emissions produced, intensity targets aim to reduce emissions per unit of economic output. Absolute emissions of a company with intermediate intensity targets can still increase due to growth in output. Gross emission projections based on absolute reduction targets have higher certainty, as growth in output is already factored in. Many companies select a base year for reporting emissions, enabling them to benchmark the emissions in later financial years and intermediate targets. Base year data together with the emissions data from the latest inventory year is documented in the quality assessment to assess past reduction achievements.

Some net-zero commitments only cover CO_2 emissions rather than all GHG emission, while others do not clearly indicate which operations of the company are covered by the target. Transparency is indispensable for an emissions reduction commitment of high quality. Best practices in terms of transparency are to have the target verified by SBTi as being in line with a pathway to limit the global rise in temperature to 1.5°C. Emissions data and an outline of the strategy should be shared with CDP.

Apart from reducing emissions from own operations, suppliers and clients should be given the ability to reduce emissions in the value chain as well. This can be done by assessing design and use characteristics of the products and services the company produces. Although Scope 3 emission reductions are difficult to measure and could easily be claimed by multiple entities, the quality of a reduction commitment improves when it shows a company has put thought in reducing emissions from cradle to grave.

2.2.2. Emissions accounting

Companies often do not have access to emissions data from sources they do not directly control, or experience difficulties accurately monitoring them. Companies rather focus on assessing and reducing Scope 1 and 2 emissions. Pollution from business travel, accounted for in Scope 3, is an exception to this. These emissions are regularly included in net-zero commitments because of their significance, data availability and unambiguous link with the company.

Some companies do not report emissions according to the GHG protocol in their environmental reports. As data that is voluntarily submitted to CDP must adhere to this standard, the DDL dataset is consulted to find more information about emissions per scope. In case companies have not shared their data with CDP, the division of emissions per scope is based on companies that operate in the same sector.

Carbon offsetting

The quality assessment differentiates between three types of carbon offsets. Table 1 is an adaptation to the *Taxonomy of Carbon Offsets* by the University of Oxford (2020) with the inclusion of six project categories identified by Ecosystem Marketplace (2019) in the first column.

Avoided emissions refer to the potential of adding a smaller, but still positive, amount of GHG emissions to the atmosphere (Tanzer & Ramírez, 2019). An emission source is replaced with a less polluting technology, making the achieved reduction dependent on the reference scenario. Emissions from the reference scenario can be overestimated and project-attributable emissions can occur outside the spatial scope of the project, leading to carbon leakage (Wunder, 2008). The additionality of avoided emissions offsets is also difficult to prove.

Table 1 - Types of carbon offsets distinguished in this study - adaptation to table from University of Oxford (2020)

Avoided emissions	**Natural sequestration**	**Technological sequestration**
-Renewable energy	-Avoided damage to ecosystems	-Mineralisation
-Waste disposal	-Ecosystem restoration	-Enhanced weathering
-Household devices	-Afforestation & reforestation	-Direct Air Capture + Carbon Storage
-Chemical processes / industrial manufacturing	-Changes to practices that retain already-stored carbon	-Bioenergy with Carbon Capture and Storage
-Energy efficiency / fuel switching	-Soil carbon enhancement	
-Transportation		
No storage	Short-lived storage	Long-lived storage

All offsetting strategies related to nature, such as afforestation and avoided damage to ecosystems, are lumped together in one category: Natural carbon sequestration. This category distinguishes itself from the other two categories by its higher risk of reversal. Achieved reductions are impermanent when carbon sequestration is reversed. Some argue that forest can be used as temporary carbon sinks, giving us time to develop more permanent solutions (Olschewski & Benítez, 2005). Based on this logic, expiring offset credits were called into existence, which require buyers to replace the credits over time. However, this further complicates the accounting process and to this date, the vast majority of natural sequestration offsets do not expire (Galik et al., 2016).

Technological sequestration physically removes GHG emissions from the atmosphere, the method is also referred to as carbon removal. In terms of additionality, technological sequestration offsets are generally favoured over avoided emissions and natural sequestration offsets (University of Oxford, 2020). Technological sequestration distinguishes itself from natural sequestration in the required human intervention and the permanence of the stored carbon. Removed carbon emissions can be safely and permanently stored in geological reservoirs or minerals and there is a low risk for replacement of emissions elsewhere. Of course, the total quantity of greenhouse gases removed should be greater than the sum of emissions produced during the removal and storage process. These upstream and downstream emissions should be included in the emission balance of the project (Tanzer & Ramírez, 2019). Technological sequestration projects are not yet operational at large scales.

Companies primarily purchase offsets to compensate for Scope 1 emissions. Some companies set up offsetting programs for their customers, enabling customers to compensate for emissions resulting from the use of the company's products. Shell for example, offers carbon credits to reduce or neutralise emissions associated with the use of their fossil fuel products[2]. Customers, rather than companies, pay to reduce the company's Scope 3 emissions. Therefore, these offsetting programs are considered not to contribute to the quality of the companies' emissions mitigation strategies.

[2] Shell (n.d). Working with customers to compensate for their emissions. Retrieved 15 February 2021, from https://www.shell.com/shellenergy/othersolutions/welcome-to-shell-environmental-products/working-with-customers-to-compensate-for-their-emissions.html

Electricity procurement

Emissions resulting from energy procurement are accounted for in Scope 2 of the GHG protocol. The amount of Scope 2 emissions calculated with the location-based approach can differ from that of the market-based approach when the carbon intensity of procured energy deviates from the grid average. The carbon intensity depends on the used form of energy generation and is influenced by energy contracts and other legal instruments companies purchase. By subtracting market-based emissions from location-based emissions, the company's individual reduction efforts become apparent.

EACs are inherent in all green power procurements, from unbundled EACs to investing in your own RE-E generation project (Critchfield, 2015). Unbundled EACs are purchased to nullify emissions from energy purchased elsewhere and make up 85 percent of RE-E purchases in the US[3]. Bundled EACs can be received from direct long-term financial commitments (i.e., PPAs), own RE-E projects and other contracts with utility suppliers. Companies with large and clustered demand for heat, steam or electricity can opt to locally produce RE themselves. On-site RE production has a high certainty of replacing energy produced from fossil fuels. As on-site energy is not procured but generated, emissions are accounted for under Scope 1. EACs associated with an on-site project must first be retained in order to claim to be using RE-E (Critchfield, 2015).

Although EACs can be seen as the currency of RE-E markets, not each EAC is worth the same. Bundled EACs are more costly and likely have higher additionality. However, unbundled EACs and bundled EACs are almost indistinguishable. Bundled EACs are difficult to attain, their acquirement is therefore expected to be celebrated and explicitly mentioned in environmental reports, as is done be several companies studied (Apple, 2019; Vodafone Group Plc, 2019). Companies that report lower emissions with the market-based approach but do not elaborate on their RE-E strategy are assumed to purchase unbundled EACs.

All types of EACs can directly cancel out Scope 2 emissions under the GHG protocol with the market-based accounting method (United States Environmental Protection Agency, 2016). EACs are also allowed to be incorporated into reduction targets verified by the Science Based Targets initiative (SBTi) (CDP et al., 2020). SBTi is a partnership between CDP, World Resources Institute (WRI), the United Nations Global Compact (UNGC), and the World Wide Fund for Nature (WWF) where companies can voluntarily get their net-zero commitments verified. 2˚C and especially 1.5˚C aligned SBTi targets signal a sound and ambitious emission reduction commitment. SBTi identifies 80% and 100% RE-E procurement by 2025 and 2030 respectively, as threshold for a reduction strategy consistent with emissions scenarios that limit global warming to 1.5°C. The organisation recommends companies to report Scope 2 emissions with both the location-based and the market-based approach. However, one consistent approach shall be used to set and track progress towards the reduction target (CDP et al., 2020).

[3] FirstClimate (n.d) Energy Attribute Certificates. Retrieved 16 February 2021, from https://www.firstclimate.com/en/energy-attribute-certificates/

2.3. Impact assessment

The impact assessment compares current Scope 1 and 2 emissions and reduction targets of companies from the Claimed Emissions dataset with the Realistic Emissions dataset. The companies included in both datasets are identical, but their emissions and targets are not.

2.3.1. Claimed Emissions

The Claimed Emissions dataset consists of companies' base year Scope 1 and 2 emissions and their respective absolute reduction targets. Companies that do not report their emissions are excluded from the analysis, so are companies without net-zero, neutral or similar commitments. Therefore, all but one absolute reduction targets in the Claimed Emissions dataset are set at 100%. PetroChina, Asia's largest oil and gas producer, is an exception, as the company made a 'near-zero' emissions commitment[4]. This commitment is interpreted as a 95% absolute reduction of Scope 1 emissions, Scope 2 emissions are excluded due to ambiguousness.

Intermediate targets are omitted to allow for a fair comparison with the Realistic Emissions dataset, where they are omitted due to complexity constraints. Intermediate targets are often in line with the final reduction target of the company, adding little detail to the reduction trajectory. 100% RE and RE-E targets are also omitted in the assessment because of the same complexities in creating intermediate values in the Impact Model and to maintain the focus on net-zero. Moreover, as intermediate targets are left out of the dataset, the most recent emissions data can be taken for the base year. Emissions data from the latest inventory year gives the best indication of a company's current emissions and reduction strategy. Emission reductions from earlier years are considered irrelevant, as this study focuses on the potential of future emission reductions, not on past achievements.

Only Scope 1 and 2 emissions are reported in the dataset. Scope 3 emissions are omitted as they are prone to be accounted for by multiple entities (double counting) and companies have less control over them. Equity emissions - emissions originating from a separate company of which the analysed company is shareholder - are omitted from the analysis for the same reasons.

If a company makes multiple emissions statements, Scope 1 and 2 emissions which receive most attention in the company's reports or website are selected for the Claimed Emissions dataset. An example of this are the emissions that are used in graphs for achieved and targeted emission trajectories. In most cases, this is the lowest account of emissions. A lower account of emissions can be achieved by including external reduction measures such as offsets and RE procurement. The majority of Scope 2 emissions in the Claimed Emissions dataset are calculated using the market-based accounting method. The Scope 2 emissions of Danish company TDC A/S are an exception to this, as can be read in Box 1.

[4] Based on https://www.reuters.com/article/us-china-petrochina-results-idUSKBN25N1CC, Retrieved 12 October 2020.

Box 1 - Scope 2 emission reporting - TDC A/S

When a company has a progressive RE procurement strategy, it commonly uses the market-based accounting method to report Scope 2 emissions. By choosing the market-based approach, a company can highlight the difference it has made in comparison to the grid average. When a company has not made strides to include renewables in its energy portfolio however, the emissions of its energy procurement may be worse than the grid average emissions calculated through the location-based emission approach.

A decreasing amount of total Scope 1, 2 and 3 emissions over the past decade are used by TDC A/S, the largest telecommunications company in Denmark, to celebrate their shrunken carbon footprint. The main contributor to this achievement is the reduction in energy consumption through energy efficiency measures. 31.803 out of the proclaimed total of 42.582 tonnes, roughly 75%, of TDC A/S CO_2 equivalent (CO_2-eq) emissions can be traced back to energy procurement (Scope 2). The 31.803 tonnes of Scope 2 emissions are calculated using the location-based accounting approach, thus using the average local grid emission factor.

However, the market-based Scope 2 emissions of the telecommunication company turn out more than twice as high (TDC Group, 2019). The achievement of reducing their total emissions of 2019 by 9.617 tonnes (t) CO_2-eq compared to 2018 shrinks in significance when 46.835t could have been saved by procuring energy comparable to the grid average. Not to mention that part of their reduction can be attributed to the lowered grid emission factor over the year of 2018 and even more emissions could have been avoided by adhering to an ambitious RE procurement strategy.

2.3.2. Realistic Emissions

The Realistic Emissions dataset takes the expected effectiveness of emission reduction methods into account. Achieved emissions and future targets are recalculated based on an evaluation of their reduction strategy. The Impact model is developed to process this evaluation of achieved and targeted Scope 1 and 2 emissions. It does so by applying a correction factor for the effectiveness of external reduction methods. External reduction methods include carbon offsets and RE procurement. The effectiveness of on-site RE generation and carbon capture and storage (CCS) are also considered. Own emission reductions are assumed to be realistic as they are, for there is little room for fraud in reporting under the Greenhouse Gas protocol. This assumption comes with the expectation that companies do not make reduction claims by outsourcing polluting activities.

Other parameters measured in the quality assessment are not incorporated into the model because they are complicated to relate to emissions in a quantitative context. Examples of omitted parameters are the planning process of the reduction strategy and whether the company has separate targets for emission reductions and removals.

To calculate the realistic emissions, an overview of the reduction methods that are applied is required. The reduction strategy corresponding to the base and target year thus has to be analysed for each company, wherein estimates are made about the use of several external reduction methods.

Intermediate targets are excluded from the Impact model as they are complex and time-consuming to process while they add relatively little extra detail to the emissions trajectories. The emissions data from latest inventory years are not calculated separately from the original base year emissions data due to similar constraints. Instead, the emissions data from the latest inventory year replace the data from the original base years, as was done in the Claimed Emissions dataset. The base years for companies are thus the same in both datasets, the amounts of emissions are not. The original base year emissions data can be overwritten as they are no longer directly tied to a target.

Box 2 - Determining absolute reduction target - IAG

Aviation is one of the sectors where emissions are hard-to-abate in the near future. While air transport is expected to increase in the coming decades, there are few options to reduce fossil fuel consumption. The International Airlines Group (IAG), owner of British Airways and Iberia among others, reported almost 31Mt CO_2-eq Scope 1 emissions for the year 2020 (International Airlines Group, 2019). The company already compensates for part of its emissions by buying forestry offsets and plans to increase its carbon offsetting efforts in the coming decades, as can be seen in Figure 2 below.

The absolute reduction target calculated in the Impact model relates to the base year emissions data. The amount of external emissions reductions are therefore also determined in relation to the base year. The additional efforts required to counterbalance increasing emissions due to company growth are not grasped by the model.

On first sight, less than half of IAG's carbon emissions need to be offset in 2050 to achieve net-zero. In relation to the base year emissions however, carbon offsets and removals make up 93.8% of the reduction below current levels. That is because the majority of sustainable aviation fuels and new aircraft and operations are used to counterbalance the increase in emissions after 2020. Sustainable aviation fuels and new aircraft and operations are considered own reduction methods, they are therefore considered as effective as IAG claims them to be. The gross emissions trajectory of IAG, displayed in yellow, only reduces by 6,2% over 3 decades. The own emission reductions decrease the carbon intensity of flying but this effect is negated in absolute terms as airline activity increases.

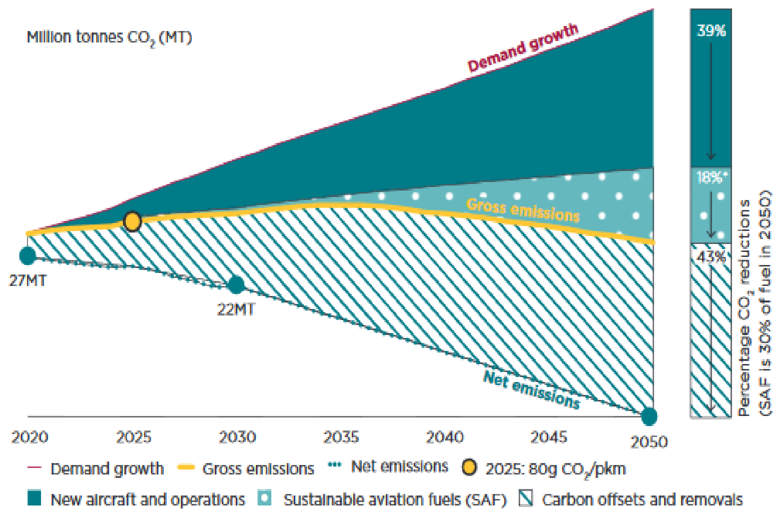

Figure 2 - IAG emissions trajectory and reduction strategy (International Airlines Group, 2019)

The aggregation tool calculates the emission trajectories on the basis of absolute reduction targets. Intensity targets have to be recalculated to absolute targets in the Impact model to be understood by the tool. This transformation requires assumptions about the growth rate of a company's emissions. The ambiguity and inaccuracy of the restated target increases, the further the base and target year are apart. Many intermediate targets are formulated as intensity targets, which would have added an extra element of complexity and uncertainty to their reformulation in the Impact model.

Three out of the four analysed fossil fuel companies, BP, Shell and Total, have added intensity targets to their net-zero commitments, which are all set for 2050. The uncertain future of fossil fuel companies and the inclusion of offsets and CCS into the calculation of their intensity target further complicate the transformation into an absolute target. Since a complex equation that attempts to address these determinants can give a false sense certainty, the intensity targets are simply halved to come to the absolute targets for 2050. An intensity target of 65% is thus transformed into 32.5% of absolute own emission reductions. The intensity targets of the fossil fuel companies are included in the dataset in spite of their uncertainties because they provide the best available approximation of the amount of emissions they plan to reduce themselves.

In case of data scarcity, assumptions are made about the types and amounts of applied external emission reduction methods. For current emissions, companies are only assumed to purchase offsets when this is implied in their environmental reports or on their websites. Scope 1 emissions calculated according to the GHG protocol do not include the use of carbon offsets. When a company purchases offsets, these emissions are subtracted from the reported Scope 1 emissions in a separate column. In some instances, Scope 2 emissions are offset as well. The amount and type of offsets purchased determine the amount of emissions that is subtracted by the Impact model. Companies that do not elaborate on the price and type of carbon offsets are assumed to purchase natural sequestration offsets. In practice, this offset type is also most popular among studied companies that do elaborate on their offsetting strategy. Companies can also purchase offsets related to technological carbon sequestration or invest in CCS or on-site RE generation. These external reduction methods are only used as input for the Impact model if their (planned) use is indicated in company documents. The use of avoided offsets is formulated as (100% - use of natural sequestration offsets), while PPA use is formulated as (100% - use of unbundled EACs). This is done in preparation for the sensitivity analysis.

The type of company and selected target year influence the assumed reduction strategy for Scope 1 emissions. Companies with reduction targets scheduled far in the future, ambitious strategies and many possibilities to reduce, fall into the 'low' category. 15% of their Scope 1 emissions are assumed to be reduced externally when an offsetting strategy is not discussed. Companies in hard-to-abate sectors such as heavy industry, aviation or fossil fuels are expected to heavily rely on external reduction methods to achieve their net-zero emissions commitments. These companies are categorised under 'high', where I assume 55% of Scope 1 emissions to be reduced externally when this is not specified. This value is considered reasonable, as several more transparent companies rely on external reduction methods for fifty percent or more to reach net-zero. Companies are filed under the 'medium' category when they underperform on one or two of the characteristics shared by the 'low' category.

When companies are untransparent about their Scope 2 emissions reporting, they are assumed to use the market-based accounting approach where 20% of the energy purchases are renewables. Unbundled EACs and PPAs are assumed to make up 95% and 5% of this RE procurement respectively. When unclear, PPAs make up a relatively small fraction of the assumed RE procurement as I assume most companies would mention them explicitly. When the partition of renewables in the energy portfolio is known but the methods applied are not, the same division is assumed. RE procurement is already incorporated in the reported Scope 2 emissions when the market-based accounting method is applied. Since the Impact model assumes a lower effectiveness of unbundled EACs and PPAs than companies do, their realistic emissions turn out to be higher.

Few companies specify the amount of Scope 2 emission reductions that can be ascribed to energy efficiencies in the target year. Unless carbon offsets are acquired, a company has to be fully powered by renewables to achieve net-zero Scope 2 emissions. The Impact Model does not account for growth in energy consumption. Instead, companies are assumed to reduce their specific as well as their absolute energy consumption in the target year. The remainder of Scope 2 emission reductions achieved by purchasing RE. Reliance on RE procurement is increased from 80% to 95% for companies with reduction targets less than ten years in the future because energy efficiencies have less time to materialise. Unless stated otherwise, unbundled EACs and PPAs are assumed to make up 95% and 5% of RE procurement respectively for the target year as well.

Table 2 - Emission reduction strategy in case unclear - amounts

Scope 1 - base year: use of offsets *(denoted with 'X_{B1}')*		0%
Scope 2 - base year: use of offsets *(denoted with 'X_{B2}')*		0%
Scope 2 - base year: use of RE *(when only market-based emissions are mentioned, denoted with 'Y_B')*		20%
Scope 1 - target year: use of offsets *(denoted with 'X_{T1}')*	Low	15%
	Medium	35%
	High	55%
Scope 2 – target year: use of offsets *(denoted with 'X_{T2}')*		0%
Scope 2 – target year: use of RE *(other part is energy efficiencies, denoted with 'Y_T')*		80%
Scope 2 – target < 10 years: use of RE *(other part is energy efficiencies, denoted with 'Y_T')*		95%

Use of RE in the base year and target year stated in Table 2 is not directly comparable. Use of RE in the base year relates to the amount of energy originating from renewable sources, while use of RE in the target year denotes the importance of RE in decreasing Scope 2 emissions to zero. Unless offsets or CCS are used, all energy procured in the target year is assumed to be sourced renewably. The part of emissions that is not addressed with RE procurement, offsets or CCS is decreased through energy efficiencies. Changes to annual emissions due to company growth or the average grid emission factor are not considered by the model. The importance of growth and the decreasing grid intensity factor differs per industry and region but work in opposite direction.

Table 3 - Emission reduction strategy in case unclear - types

Scope 1 & 2 - base year & target year: addressing natural sequestration when offsetting *(denoted with 'A_B / A_T')*	100%
Scope 1 & 2 - base year & target year: addressing avoided emissions when offsetting *(denoted with 'B_B / B_T')*	(1-A)
Scope 2 - base year & target year: use of unbundled EACs in RE portfolio *(denoted with 'L_B / L_T')*	95%
Scope 2 - base year & target year: use of PPAs (including tariffs) in RE portfolio *(denoted with 'K_B / K_T')*	(1-L)

The assumed reliance on natural sequestration and unbundled EACs is supported by companies that are transparent about their external emission reduction methods, where these methods also make up the majority of their offset and RE portfolio. Preference for these methods can be explained by their relatively high availability and low price. Not surprisingly however, their expected effectiveness is low.

Natural carbon sequestration primarily consists of offsets related to afforestation, reforestation and avoided deforestation. Reason for this probably is the positive connation with forests related to recreation, natural aesthetics and diversity of life (Gössling et al., 2007). This connotation to forests sells well to customers.

Natural sequestration projects have a high risk of reversal. Unlike the avoided use of a litre of diesel or a filtered tonne of CO_2 stored in a geological reservoir, a tree can be cut or burned a year from now. The avoided or removed emissions are nullified by such an event but will not be accounted for by the company that bought the corresponding offsets. The area set aside for forestry projects has to remain reserved indefinitely unless the grown crops are used for the production of biofuels which substitute for fossil fuels (Gössling et al., 2007). Biomass production can require substantial energy inputs resulting in emissions, which should be deducted from the carbon forests capture (Holden & Høyer, 2005). Afforestation also increases competition for land that could also be used for agricultural practices. This could increase populations at risk of hunger and food prices (Doelman et al., 2020).

When afforestation projects are compared to natural regeneration of a land area after a bush fire, the net carbon emissions can actually be positive for the first twenty to thirty years. Removal and processing of existing stems prior to plantation, increased decomposition of organic matter due to preparation of the soil and the required energy inputs to achieve this generate GHG emissions (Levasseur et al., 2012). The project's net carbon balance depends on local environmental aspects and the natural regenerative capacity of the area. The negative carbon balance of the project's first years raises questions about the validity of carbon offsets of recent afforestation initiatives and aforementioned expiring offset credits. Offsets should not account for carbon sequestrations that have yet to accrue, especially with the increased risk drought and heat-induced tree mortality due to climate change (Allen et al., 2010).

Considering the high risk of reversal and non-additionality, I assume the effectiveness of natural sequestration offsets in the Impact Model to be five percent. In other words, for every tonne a company offsets with natural sequestration projects, the model expects only fifty kilograms (kg) of CO_2 equivalent emissions to be permanently removed from the carbon cycle.

I assigned a slightly higher effectiveness value to the avoided emissions offset category as their reductions occur in real time. Unlike natural sequestration projects with initially negative carbon balances, avoided emissions replace fossil fuel emissions directly. Avoided emissions projects can be subdivided into projects which improve energy efficiencies and clean(er) energy projects. Energy efficiency programs can be subject to the Jevons paradox, meaning that gains in efficiency can be negated by a resulting increase in consumption.

The majority of projects supported by companies in the avoided emissions category address RE generation. An advantage of RE over natural sequestration is the relative ease to prove a tonne of carbon has not been emitted. Difficulty lies in proving the additionality of instruments that financially support the creation of RE projects. Unbundled EACs are assigned the same effectiveness as avoided emissions offsets in the Impact Model, because both instruments fundamentally address the same emission reductions.

Box 3 - Reducing emissions with renewable energy - Sky

Sky, a British media and telecommunication conglomerate, is one of few companies I encountered which is transparent about the offsetting projects it supports. The majority of projects Sky supports address RE generation. The remainder of offset purchases goes to natural sequestration projects oriented towards afforestation and reforestation in the Global South (Sky, 2020).

Sky also claims to have supported RE projects labelled under the REGO and GO standard. REGO is an abbreviation for Renewable Energy Guarantees of Origin, while GO is short for Guarantees of Origin. Both refer to the European scheme for EACs. REGO and GO projects generate EACs instead of offset credits, expressed in megawatt-hours rather than tonnes of carbon emissions. Sky's inclusion of RE projects generating EACs in a list of offsetting projects verified by the Verified Carbon Standard (VCS) suggests the projects are interchangeable and of similar effectiveness. Partly due to the apparent indifference of Sky between RE projects from the (RE)GO and VCS standard, the effectiveness of unbundled EACs is set equal to the effectiveness of emission avoidance offsetting projects.

In the course of 2020, the price of European energy certificates, Guarantees of Origin (GO), decreased to a record low of €0.10 per MWh[5]. Considering Europe's average carbon intensity of 235kg CO_2-eq per MWh in the energy grid, a mere €0.43 (= US$0.52) allows companies to cancel out one tonne of Scope 2 carbon emissions (IEA, 2020). On average, RE offsets were priced at US$1.40 in 2019 (Donofrio et al., 2020). The pandemic of 2020 likely resulted in lower prices, similar to the price trend of GOs. The oversupply and associated low prices are strong indicators that additionality of these instruments is low (Mulder & Zomer, 2016; Gillenwater et al., 2014). Substantial volatility in unbundled EAC prices can also discourage from investment in new RE projects (Kim, 2020).

[5] Commerg. (2021, December 4). Guarantees of Origin in 2020 – Seemingly higher demand but ever lower prices. Retrieved 10 February 2021, from https://commerg.com/insights/guarantees-of-origin-in-2020-seemingly-higher-demand-but-ever-lower-prices/ /

The majority of European GOs are generated by decades-old hydropower plants in Scandinavia (AIB, 2019; Hast et al., 2015). The certificates have no influence on the hydropower generation capacity and are sold to the rest of Europe for additional profits. Locally sourced RE-E certificates from newer projects possibly grant higher additionality and can also cost more than €7,- per MWh (Wielders et al., 2020). Companies hardly differentiate between EAC source and price however, complicating the assessment of their external emission reduction strategy's effectiveness.

Apart from ambitious companies with net-zero emissions commitments, emissions from energy consumption are generally calculated with the local average grid emission factor. The emission factor is calculated with the generated amount of electricity in the grid. Only recently are certificates, contracts and supplier-specific factors subtracted from the location-based grid emission factors. The residual mix factor resulting from this subtraction has a higher emission intensity because the remaining percentage of RE is lower. As of 2020, the residual mix factors still are not widely available (CDP, 2020). The emission reductions that companies claim with offsets and EACs can therefore also be included in the average grid emission factor, leading to an overestimation of Scope 2 emission reductions due to double counting (Gillenwater, 2013).

Carbon capture and storage projects are another method to reduce emissions externally. Annual CCS capacity was 35-40 megatonnes (Mt) of CO_2 in 2018 (National Academy of Sciences, Engineering and Medicine, 2018). Although CCS is generally utilised by industrial companies and not sold as offsets, the technology is treated similarly to offsets in the Impact model. 85% to 90% of CO_2 generated by a power plant can be captured by the absorber (Wilberforce et al., 2019). Considering the energy required to capture and permanently store CO_2 from a concentrated gas stream, CCS can reduce 65-85% from fossil fuel combustion emissions (Benson et al., 2012). This required energy to execute CCS is already accounted for in Scope 1 emissions for companies that manage their own CCS projects. Considering leakages during transport and storage, I assigned an effectiveness of 85% to CCS. The effectiveness of CCS offsets would be lower, as energy requirements then have to be internalised. All analysed companies utilise CCS themselves rather than buying CCS offsets on a public market.

I assign an effectiveness of 100% to Technological sequestration (TS) projects as they are technically innovative, very expensive and closely monitored (Keith et al., 2018). Only 17 direct air capture with carbon storage (DACCS) installations, a type of TS, were operative in 2018. Other TS projects are also scarce. CO_2 has to be captured from the atmosphere at concentrations of roughly 0.04%, while CCS projects filter air with CO_2 concentrations of 15% and 5% for coal and natural gas power plant emissions respectively (National Academy of Sciences, Engineering and Medicine, 2018).

Keith et al. (2018) indicate that levelized costs of US$94-232 per tonne of CO_2 directly captured from the air are achievable in the near future. Verifiable and permanent TS offset credits are scarce and expensive. This limits commercial demand. The costs of TS projects can be driven down when the technology is improved and scaled up over the years. The price of TS projects has potential to drop below US$60 per tonne of CO_2 by 2050 in major parts of the world (Breyer et al., 2019). The life cycle and stability of sorbents, which physically or chemically bind to CO_2, are critical parameters that influence costs (Sutherland, 2019). Permanence of TS emission reductions is not to be neglected to drive down costs.

In some countries, above-market energy prices are charged by energy suppliers to develop new RE projects. These prices are often fixed for multiple years and are called feed-in tariffs (FITs). FITs are commonly integrated in PPAs, ensuring operational costs are covered after completion of the project. Considering the long-term income security to energy utilities both instruments provide, FITs are conjoined with PPAs in this study. The higher price per MWh and permanence of payment has a higher chance to instigate RE investment.

RE delivered through PPAs is double counted in regions where residual mix grid emission factors are not yet calculated. PPAs can also be signed for already existing RE project. Such PPAs are only additional if the installation would stop operating otherwise. Apart from defects, RE installations can also stop operating when they are no longer profitable. Changes in governmental policies can affect RE profitability. For instance, the German Renewable Energy Sources Act, which abolishes price guarantees for RE in the form of fixed feed-in tariffs by 2021[6].

After reducing energy consumption, PPAs are often the best option for companies to address energy emissions. Considering the additionality and limited risks, I assigned an effectiveness of 80% to PPAs in the Impact Model.

Companies with larger energy requirements can opt to produce RE locally themselves. On-site RE production has a high certainty of replacing energy produced from fossil fuels. On-site RE generation is not included in the regional grid emission factor as the energy is not supplied to the shared grid. Since there is no risk of double counting and the only investor and beneficiary of an on-site RE installation is the company itself, this reduction method is assigned an effectiveness of 100% in the Impact Model. On-site RE does not affect market-based Scope 2 emissions. Emission reductions achieved by on-site RE generation are only included in base year Scope 2 emissions when the company indicates the amount of RE it consumed and applies the location-based accounting method.

Table 4 - External reduction methods - effectiveness

Natural sequestration – offsets *(denoted with ‘α’)*	5%
Avoided emissions – offsets *(denoted with ‘β’)*	10%
Technological sequestration – offsets *(denoted with ‘γ’)*	100%
Carbon Capture & Storage (CCS) *(denoted with ‘δ’)*	85%
Unbundled Energy Attribute Certificates (EACs) *(denoted with ‘κ’)*	10%
Power Purchase Agreements & Tariffs (PPAs) *(denoted with ‘λ’)*	80%
On-site RE generation *(denoted with ‘μ’)*	100%

[6] Appunn, K. & Wehrmann, B. (2019, October 21). Germany 2021: when fixed feed-in tariffs end, how will renewables fare? Retrieved 11 February 2021, from https://energypost.eu/germany-2021-when-fixed-feed-in-tariffs-end-how-will-renewables-fare/

Recalculation

The Impact Model relies on equations to interpret the reduction strategies of companies. Current emissions and reduction targets are recalculated based on assumptions described in the previous chapter. Emission parameters, all denoted with '.ems', are expressed in tonnes of CO_2 equivalent [t CO_2-eq]. All other input parameters are dimensionless, expressed in percentages.

Current emissions - Scope 1

Emissions are reported according to the GHG protocol, wherein offsets cannot be subtracted. Offsets thus always decrease the realistic emissions *($Real.ems_1$)* compared to the reported Scope 1 emissions *($Rep.ems_1$)*. The decrease in realistic emissions depends on the amount and type of offsets bought. Scope 1 emissions are calculated with the following Equation:

$$Real.ems_1 = Rep.ems - X_{B1} \cdot Rep.ems_1 \cdot (\alpha \cdot A_B + \beta \cdot B_B + \gamma \cdot C_B + \delta \cdot D_B) \qquad \text{Eq1}$$

The used number of offsets *(X_{B1})* is expressed in a percentage relative to the reported base year emissions (Table 2). A_B, B_B, C_B and D_B represent the importance of forestry, avoided emissions, CCS and direct air capture reductions in the company's external reductions portfolio (Table 3). Subscript 'B' depicts parameters from the base year strategy, while subscript '1' depicts Scope 1 emissions. They are expressed in relative terms to each other with a sum of 1. When a company only purchases forestry offsets, as is assumed when more detailed information is lacking, A_B becomes one while B_B, C_B and D_B are set to zero.

α, β, γ and δ represent the effectiveness of forestry, avoided emissions, CCS and direct air capture emission reductions respectively, and are expressed in percentages. They are constant for each company (Table 4) and will be tested separately in the sensitivity analysis.

Current emissions - Scope 2

Calculating Scope 2 emissions is more complicated than Scope 1 emissions. Scope 2 emissions can be reduced with RE procurement as well as offsets. RE procurement is already subtracted from the reported Scope 2 emissions with the market-based accounting method. RE claims that are not included in the reported Scope 2 emissions and energy bought with a higher carbon intensity than the average grid emissions factor are also considered by the Impact model. To do so, multiple equations are developed. Equation 2 is applied when companies report two separate accounts of Scope 2 emissions using both accounting methods.

$$\begin{aligned} Real.ems_2 = {} & LB.ems - X_{B2} \cdot Rep.ems_2 \\ & \cdot (\alpha \cdot A_B + \beta \cdot B_B + \gamma \cdot C_B + \delta \cdot D_B) \\ & - (LB.ems - Rep.ems_2) \cdot (\kappa \cdot K_B + \lambda \cdot L_B) \end{aligned} \qquad \text{Eq2}$$

As the symbols represent the same parameters, the first part of Equation 2 shows many similarities to Equation 1. Offsets are now subtracted from location-based emissions *(LB.ems)*, which are higher than the company's Scope 2 emissions reported with the market-based approach *($Rep.ems_2$)*. X_{B2} represents the number of offsets bought relative to the reported Scope 2 emissions, where 'B' once again denotes parameters from the base year strategy, while subscript '2' indicates Scope 2 emissions.

The difference between location-based emissions *(LB.ems)* and market-based emissions *(Rep.ems2)* is achieved by purchasing unbundled EACs and PPAs. K_B and L_B represent the relative importance of EACs and PPAs in the company's RE procurement strategy, while κ and λ represent their assigned effectiveness.

Equation 2 is also used when market-based emissions are higher than location-based emissions. In that case, market-based emissions are filled in for both reported emissions *(Rep.ems2)* and location-based emissions *(LB)*. The lower location-based emissions reported by the company are not used as input for the model. In these instances, it has to be checked whether the number of offsets *(X_{B2})* are expressed relative to the (higher) market-based emissions. M_B

When location-based emissions are not reported, market-based emissions are recalculated with companies' percentual consumption of RE *(Y_B)*.

$$Real.ems_2 = \frac{Y_B}{1 - Y_B} \cdot Rep.ems_2 \cdot ((1-\kappa) \cdot K_B + (1-\lambda) \cdot L_B + (1-\mu) \cdot M_B) - X_{B2} \cdot Rep.ems_2 \cdot (\alpha \cdot A_B + \beta \cdot B_B + \gamma \cdot C_B + \delta \cdot D_B) + Rep.ems_2 \quad \text{Eq3}$$

RE procurement subtracted from the (unreported) location-based emissions is originally assigned 100% effectiveness by companies. To compensate for the overestimation of effectiveness, the difference in effectiveness of EACs $(1-\kappa)$, PPAs $(1-\lambda)$ and on-site RE $(1-\mu)$ is added to the market-based emissions *(Rep.ems2)*. However, this compensation is calculated only over the amount of energy that is procured from renewable sources ($\frac{Y_B}{1-Y_B} \cdot Rep.ems_2$). In the second part of the equation, offsets are again subtracted from the reported emissions.

Companies can also report RE procurement separately. In those cases, Scope 2 emissions are calculated with the location-based accounting method. RE procurement is subtracted from these emissions by the Impact Model to ensure realistic emissions of all companies are comparable.

$$Real.ems_2 = Rep.ems_2 - X_{B2} \cdot Rep.ems_2 \cdot (\alpha \cdot A_B + \beta \cdot B_B + \gamma \cdot C_B + \delta \cdot D_B) - Y_B \cdot Rep.ems_2 \cdot (\kappa \cdot K_B + \lambda \cdot L_B + \mu \cdot M_B) \quad \text{Eq4}$$

One can observe that on-site RE is excluded from Equation 2. On-site RE can be part of RE consumption *(Y_B)* but cannot cause differences between market- and location-based accounted emissions.

Reduction target - Scope 1

The impact model recalculates the impact of external reduction methods. The part of emissions not covered by offsets or CCS is assumed to be addressed internally, leading to directly measurable emission reductions. The realistic Scope 1 emission reduction target *(Real.Target1)* of a company with a net-zero emissions commitment is therefore calculated with Equation 5, wherein subscript ‘T’ depicts parameters of the target year strategy. The output parameter is unitless, expressed in percentages, as the two ‘.ems’ parameters [t CO_2-eq] cancel each other out.

$$Real.Target_1 = 100\% - \frac{Rep.ems_1 \cdot X_{T1} \cdot ((1-\alpha) \cdot A_T + (1-\beta) \cdot B_T + (1-\gamma) \cdot C_T + (1-\delta) \cdot D_T))}{Real.ems_1} \quad \text{Eq5}$$

Emission reduction strategies are based on the emissions companies report in the base year. Realistic emissions are lower than reported Scope 1 emissions according to the model, as offsets cannot be used to compensate under the GHG accounting protocol. If a company’s reduction strategy for the target year is unaltered in terms of amount and type of offsets bought, the realistic reduction target for Scope 1 emissions *(Real.Target₁)* is zero percent compared to the base year. Since growth is not accounted for in the model, all emission reductions are the result of changes in strategy in the target year compared to the base year. Realistic emissions in the base year *(Real.ems₁)* are used for the denominator as this is the reference scenario against which the reduction target is expressed. Thus, any Scope 1 emission reductions achieved in or prior to the base year, internally as well as externally, are not part of the reduction target value.

The intensity targets of fossil fuel companies are incorporated into the number of offsets and CCS used in the target year. For these companies, X_{T1} is one minus the transformed target (halved intensity target). In PetroChina’s case, the initial target of 100% in Equation 5 is adapted to 95%, which highlights the minor adjustments required for the Impact Model to include companies with less ambitious reduction targets.

Reduction target- Scope 2

Calculation of the reduction target for Scope 2 emissions is more difficult as companies have a larger array of options to reduce their emissions externally. The difference between assumed and realistic effectiveness of external emission reduction measures is once again subtracted from the absolute reduction target.

$$Real.Target_2 = 100\% - \frac{NoRE.ems \cdot Y_T \cdot \left((1-\kappa) \cdot K_T + (1-\lambda) \cdot L_T + (1-\mu) \cdot M_T\right)}{Real.ems_2} - \frac{Rep.ems_2 \cdot X_{T2} \cdot ((1-\alpha) \cdot A_T + (1-\beta) \cdot B_T + (1-\gamma) \cdot C_T + (1-\delta) \cdot D_T)}{Real.ems_2} \quad \text{Eq6}$$

Overestimates of offsetting and CCS effectiveness are subtracted in a manner similar to Equation 5. The difference in RE procurement effectiveness in the target year is subtracted from the emissions a company would have emitted if it would not engage in RE procurement in the base year *(NoRE.ems)*. That is because the RE procurement strategy in the base year is already subtracted from the reported Scope 2 emissions *(Rep.ems₂)* according to the GHG accounting protocol. If reported emissions are used as base value, the RE procurement strategy of the base year would be double counted.

$$NoRE.ems = LB.ems \quad \text{Eq7}$$

$$NoRE.ems = \frac{Rep.ems_2}{1 - Y_B} \quad \text{Eq8}$$

$$NoRE.ems = Rep.ems_2 \quad \text{Eq9}$$

NoRE.ems depends on the equation used to calculate the company's current Scope 2 emissions. In all cases, NoRE.ems is the higher account of Scope 2 emissions. If Equation 2 was applied to calculate realistic Scope 2 emissions *($Real.ems_2$)*, Equation 7 is used to calculate NoRE.ems. Equation 8 is used for realistic Scope 2 emissions calculated with Equation 3, while Equation 9 is applied to companies that did not subtract RE procurement from their reported emissions.

2.3.3. Sensitivity analysis

The sensitivity of the Impact Model is tested by reflecting on its assumptions. The influence input parameters have on recalculated emissions and targets is assessed, validating the model's robustness.

The sensitivity of all input parameters mentioned in Tables 2, 3 and 4 is tested individually. To measure the impact on Scope 1 and 2 emissions and reductions, I subtract five percentage points from the parameter's value while all other input parameters are held constant. When the original value is zero, five percentage points are added instead. For example, CCS is originally assumed to have an effectiveness of 85%, which is then reduced to 80%, ceteris paribus. The sum of companies' realistic emissions and reductions are measured to assess the sensitivity of the model. Differences in base and target years are not considered as these are unrelated to measuring the potential of the commitments. Whether five percentage points are added or subtracted from the input parameters has no influence on the relative deviation from the original outcomes, apart from the direction of change.

Offset and EAC effectiveness is set as exogenous assumption in the Impact Model. Alternatively, market prices can be used to determine the relative effectiveness of these measures. The price of reducing one tonne of own emissions can be set equal to the price of a permit from the European Union Emissions Trading System (EU ETS). This system enables (mandatory) participants from different industries to exchange emissions rights. The number of permits, each allowing one tonne of CO_2 equivalent emissions, in circulation is controlled by the EU. When the system functions as intended, the price of one permit reflects the price at which it is equally expensive for companies to reduce their own emissions. The average EU ETS permit price in 2019 was €25,- (roughly US$30), by Feb 1, 2021, the price has risen to €35,-[7].

[7] Based on EUA Price plot depicted by Ember-climate.org. Retrieved 12 February 2021, from https://ember-climate.org/data/carbon-price-viewer/

The average price of voluntary carbon offset credits for natural sequestration offsets in 2019 was US$4.30 per tonne of CO_2 equivalent (Donofrio et al., 2020). All other offset types identified by Donofrio et al. (2020) are filed under avoided emissions. 63.7Mt of avoided emission offsets were bought at a weighted average price of US$1.9.

Table 5 - Statistics voluntary carbon offset market 2019 - adaptation to (Donofrio et al., 2020)

	Volume [Mt CO2 eq]	Average price [US$]
Natural sequestration		
Forestry and land use	36.7	$4.3
Avoided emissions		
Renewable energy	42.4	$1.4
Waste disposal	7.3	$2.5
Household devices	6.4	$3.8
Chemical processes / industrial manufacturing	4.1	$1.9
Energy efficiency / fuel switching	3.1	$3.9
Transportation	0.4	$1.7
Total – avoided emissions	63.7	
Weighted average – avoided emissions		$1.9

The effectiveness of offsets can be derived by dividing their selling price by the price of an EU ETS permit in 2019, which is assumed to be the real cost of reducing emissions. The effectiveness of forestry offsets thereby increases to 14.3%, while avoided emissions effectiveness reduces to 6.4%. When applying the same method to unbundled EACs, which can cost as little as US$0.52 to reduce one tonne of CO_2 equivalent emissions, their effectiveness drops from 10.0% to 1.7%.

The offset procurement strategy of companies that are untransparent about their purchases can be changed to reflect the amounts sold on the voluntary carbon market. Instead of allocating 100% of offsets to natural sequestration projects, 63.5% is allocated to avoided emissions.

The intensity targets of the four fossil fuel companies included in the dataset are also assessed on sensitivity. Considering the substantial emissions of these companies, changes in the transformation of intensity to absolute targets may result in noticeable differences in the outcomes of the Impact Model. The difference in Scope 1 emission reductions is measured when transforming intensity targets directly into absolute reduction targets, rather than halving them.

The likeliness of the original model's outcomes is assessed by performing a Monte Carlo Simulation with 10,000 random iterations. Based on my own empirical estimates, I assigned reasonable ranges for all input parameters between which the values vary uniformly. An overview of the ranges is presented in Appendix B. The distributions of calculated emissions and reduction potentials inform about the robustness of the model.

2.3.4. Climate Action Aggregation Tool

The Climate Action Aggregation Tool (CAAT) is used to aggregate the impact of emission reduction target, and to integrate them into projections and scenarios. Outcomes can be used to support policy development, policy evaluation and target-setting.

The tool has been developed by NewClimate Institute with support from World Resources Institute and funding from the Initiative for Climate Action Transparency (ICAT) and the United Nations Office for Project Services (UNOPS)[8].

The CAAT determines the combined potential impact of non-sate and subnational emission reduction actions on climate pathways. Data from the Climate Action Tracker (CAT)[9], is used to develop climate pathway scenarios, such as the current policy projections (CPPs). Emission trajectories from the Claimed Emissions dataset and the Realistic Emissions dataset are compared to the CPPs pathway. After achieving the target, the remainder of emissions follows the growth rate of the reference scenario. Emissions from 2015 until the reported base year also follow CPPs' growth rate.

The tool is designed to analyse reductions in a specific country, region or city. The companies analysed in this study operate globally. Therefore, the CPP pathway is expressed in global GHG emissions. Overlaps between the analysed energy utilities and companies are minimal due to the used geographical scope in the tool. The chance that one of the analysed energy utilities' Scope 1 emission reductions affects the Scope 2 emissions of one of the analysed companies through a lower average grid emission factor is small as both entities could operate anywhere in the world. The chance for overlaps increases when both entities operate in a smaller geographical area.

2.3.5. Extrapolation

The sample of companies which are randomly selected from the modified DDL dataset can be extrapolated to approximate the reduction potential of all companies with net-zero commitments. Companies are analysed on individually expressed net-zero emissions commitments and reported Scope 1 and 2 emissions. The number of companies without net-zero commitment or reported emissions is also monitored.

By dividing the number of companies in the modified dataset (n=1535) by the sample size, one can derive the multiplication factor. To extrapolate the sample, I multiply the sample's claimed and realistic emissions and planned reductions by this factor. The extrapolated realistic reductions represent the reduction potential of companies with net-zero commitments. No estimates are made about companies that did not report Scope 1 and 2 emissions, as not to inflate the reduction potential. Companies without reported emissions or net-zero commitments effectively do no contribute to emission reductions in this study.

[8] Initiative for Climate Action Transparency. (n.d.). Climate Action Aggregation tool. Retrieved 1 March 2021, from https://climateactiontransparency.org/icat-toolbox/climate-action-aggregation-tool/

[9] Climate Analytics and New Climate Institute. (n.d.). The Climate Action Tracker. Retrieved 24 February 2021, from https://climateactiontracker.org/global/temperatures/

3. Results

3.1. Quality assessment

3.1.1. Target description

Due to a lack of standardised definitions and criteria for use, different terms for emission reduction targets are used interchangeably (NewClimate Institute & Data-Driven EnviroLab, 2020). Climate commitments become difficult to compare based on terminology alone. The occurrence of different terms for reduction targets, obtained from the 42 companies analysed in the Quality Assessment, is depicted in Figure 3. Target years and scopes are also presented in Figure 3. Some more details of the quality assessment are captured in Appendix C.

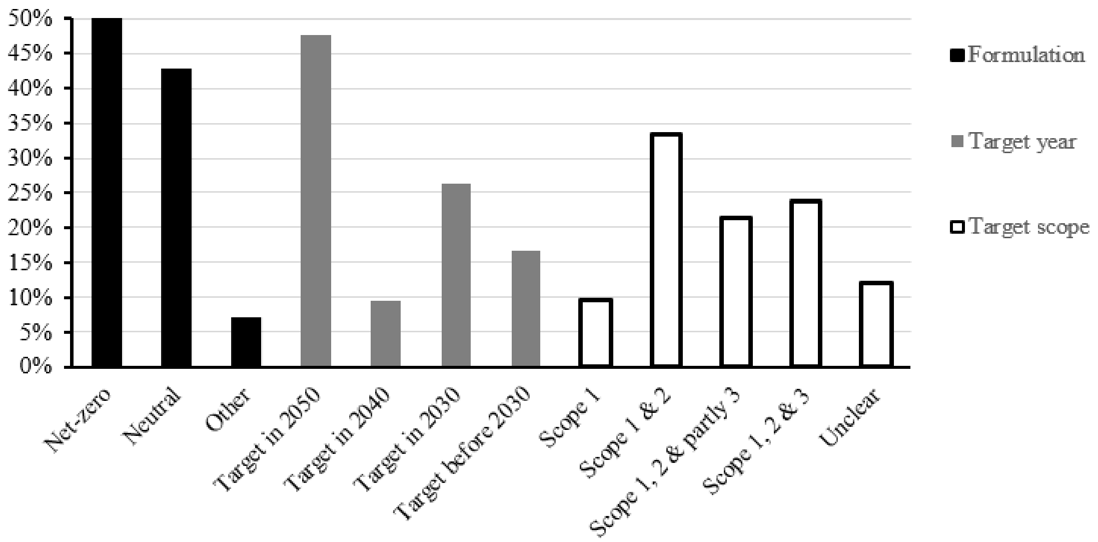

Figure 3 - Reduction target characteristics of companies analysed, n=42 in all three analyses

Companies aiming to be carbon, climate or CO_2 neutral are lumped in ‘neutral’. Two out of three companies categorised in ‘other’ aim to go beyond net-zero or neutral. H&M’s climate positive target and Microsoft’s carbon negative target[10] both aim to remove more GHG emissions than are emitted (H&M Group, 2019). PetroChina’s near-zero target is also categorised in “other”.

Box 4 - Target Terminology

Companies often use multiple terms to refer to the same target. Terminology is used interchangeably, and some companies have come up with interesting alterations to well-known terms. Not only is it confusing for the reader, companies themselves also get confused.

Thor Industries has a long-term commitment[11] to become ‘net-neutral’, which is more a term for treatment of internet traffic. OP Financial and Sky have an ultimate ambition to be ‘carbon positive’, which in its strict interpretation would be regular emitters[12] (Sky, 2019).

[10] Based on blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030/, Retrieved 24 February 2021.
[11] Based on https://www.thorindustries.com/sustainability-environmental, Retrieved 27 March 2021.
[12] Based on https://www.unepfi.org/member/op-financial-group/, Retrieved 27 March 2021.

Almost half of all analysed companies aim to reach their target in 2050. The average target year of companies with a neutrality target is due in 2035, while the average net-zero commitment should be reached in 2044. There is no clear correlation between target terminology and the scopes that are covered.

When commitments cover Scope 3 emissions, they often do so partly. Companies regularly account for emissions related to employee travel but distance themselves from emissions generated upstream or downstream in their supply chain. H&M and Apple can be applauded in this regard. H&M rewards its high-achieving suppliers, while Apple lets customers trade in old devices and has increased use of recycled materials upstream (H&M Group, 2019; Apple, 2019).

Box 5 - Inclusion of Scope 3 emissions

The GHG protocol identifies fifteen distinct categories for Scope 3 emissions (GHG Protocol, 2013). Companies are free to choose which categories they want to address in their commitment, but it is expected that the most relevant categories are selected. Telecom providers Vodafone and Singtel's Scope 2 emissions receive most attention due to their relative size compared to Scope 1. Vodafone emits 1.65Mt while Singtel emits 154 kilotonnes (kt), hence varying roughly a factor ten in size (Singtel Group, 2020; Vodafone Group Plc, 2019). Singtel's Scope 3 emissions amount to roughly 5kt, while Vodafone accounts for more than 11Mt. Singtel presumably only covers employee travel, while Vodafone includes emissions related to the use of its services and has pledged to half these in 2030.

Net-zero committers either depend less on external reduction methods or purchase assets with higher effectiveness. Realistic reduction targets are substantially lower for companies with neutrality targets for both scopes.

Table 6 - Average realistic emissions and reductions

	Neutral	Net-zero
Scope 1 base year emissions [Mt CO_2 eq]	19	16
Scope 2 base year emissions [Mt CO_2 eq]	1.4	1.5
Scope 1 reduction target	59%	71%
Scope 2 reduction target	35%	54%

Reductions do not always increase when targets are set further into the future. Commitments set in 2040 achieve the highest reductions for both Scope 1 and Scope 2 compared to the base year.

Box 6 - Emission ratios

HeidelbergCement, one of the largest building material companies in the world, only measures CO_2 emissions from purchased electricity as Scope 2 emissions. The company's Scope 1 and 2 emissions have a ratio of 200 to 1. The ratio for ArcelorMittal, another building material multinational, is 15 to 1.

Table 7 - Average realistic reductions per target year

	Scope 1 - total	Scope 2 - total	Scope 1 - annual	Scope 2 - annual
Target year: 2050	69%	44%	2.2%	1.4%
Target year: 2040	78%	68%	3.5%	3.1%
Target year: 2030	64%	49%	5.9%	4.5%
Target year: Before 2030	45%	37%	7.9%	6.8%

When the reductions are divided by the commitments' time horizons, short-term targets achieve the highest reduction rates.

3.1.2. Strategy description

Companies without clear strategy and interim targets are less likely to achieve their final reduction target. A worked out strategy and intermediate steps also support identification of solutions for harder-to-abate sectors (NewClimate Institute & Data-Driven EnviroLab, 2020). The majority of analysed companies has set interim targets, where carbon neutrality is sometimes used as an intermediate step in becoming net-zero. TDC A/S, Denmark's largest telecom company, became a signatory of the UN's Business Ambition for 1.5°C Pledge, but does not yet have a strategy to reach the net-zero requirement by 2050 (TDC Group, 2019). Instead, the interim target to become CO_2 neutral by 2028[13] was assessed in this study. Some companies have also set targets beyond neutrality or net-zero. Velux and Microsoft both aspire to become "lifetime carbon neutral"[14,15], removing the surplus of emissions produced during the whole lifetime of the company.

Table 8 - Reduction strategy characteristics

	Yes	Unclear	No
Company has an interim target	81%		19%
SBTi approved	74%		26%
If SBTi approved - 1.5 C ambition	65%		35%
Company plans to use offsets	55%	40%	5%

Three quarters of analysed companies has set emission reduction targets that are approved by SBTi. Two thirds of these companies' reduction targets are in line with a trajectory where temperature rise is held at 1.5°C above pre-industrial levels, according to SBTi. SBTi's requirements for this trajectory are to halve GHG emissions by 2030 and to hit net-zero emissions by 2050[16]. The average realistic Scope 1 reduction target for an SBTi approved target is 69%, while realistic reduction targets that are not approved by SBTi average at 52%. The difference between Scope 2 reduction target effectiveness with and without SBTi approval is

13 TDC A/S. (n.d). 100% CO_2 neutral by 2028. Retrieved 24 February 2021, from on https://tdcgroup.com/en/responsibility/environment

14 Brad Smith. (2020). Microsoft will be carbon negative by 2030. Retrieved 24 February 2021, from https://blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030/

15 Velux. (n.d). Becoming Lifetime Carbon Neutral. Retrieved 24 February 2021, from https://www.velux.com/what-we-do/sustainability/lifetime-carbon-neutral

16 SBTi. (n.d). Business Ambition for 1.5°C. Retrieved 24 February, from https://sciencebasedtargets.org/business-ambition-for-1-5c

negligible *(<2%)*. Differences between SBTi targets that are in line with a 1.5°C trajectory and SBTi targets that are not, are also negligible *(<2%)* for both scopes.

Forty percent of analysed companies does not mention the use of offsets in its public documents. This finding is in line with the finding of NewClimate Institute and Data-Driven EnviroLab (2020), where approximately half of the assessed companies is transparent about their intention to use offsets for their net-zero commitments. Many of the companies that do mention offsets in their reduction strategies do not specify their relative importance to reach the target. Two companies claim to refrain from the use of offsets to reach net-zero altogether. Maersk, world's largest container shipping company, and Enel, an Italian energy multinational, both aim to reach net-zero with own reductions through technological innovations[17] (Enel, 2019). Boston Consulting Group takes a different approach by primarily utilizing offsets to reduce Scope 1 emissions. The company plans to use high-quality offsets from the direct air capture category and expects to pay US$80 per tonne of removed carbon in 2030[18].

Fossil fuel companies also plan to use offsets to achieve their reduction targets, although they are far less transparent about it. Total, BP and Shell have set intensity targets of 60%, 50% and 65% for energy products in 2050 respectively. All three also have a net-zero emission commitment for 2050 (Total, 2020; Shell, 2021; BP, 2019). The companies have developed similar methodologies to track GHG emissions over the entire lifecycle and to calculate the carbon intensity (Total, 2020a; Shell Global Solutions UK, 2020; BP, 2019). The intensity indicators are calculated by dividing a numerator including emissions and removals by a denominator, being the quantity of energy sold.

The numerator includes: (1) Emissions related to the production and processing of energy products used by customers; (2) Emissions related to customers' use of these energy products; and (3) Negative emissions stored through CCS and in natural carbon sinks. Total Group uses the term natural carbon sinks, BP mentions land carbon projects and Shell allows all carbon offset credits as long as they meet their eligibility criteria regarding use and retirement.

Hence, emissions captured with CCS and natural sequestration projects are incorporated into the carbon intensity equation. None of the companies specifies the intended amount of CCS and offsets to achieve the intensity targets. The denominator of the equation can also be manipulated by selling energy products with lower carbon intensities. All three companies have announced to increase investments in renewables[19,20,21]. The resulting energy products dilute the average carbon intensity of energy products while fossil fuels do not have to be phased out.

[17] Mackenzie, K. (2021, January 15). Too many companies are banking on carbon capture to reach net-zero. Retrieved 24 February 2021, from https://www.business-standard.com/article/international/too-many-companies-are-banking-on-carbon-capture-to-reach-net-zero-121011500980_1.html

[18] Boston Consulting Group. (2020) BCG's Net-Zero Pledge. Retrieved 24 February 2021, from https://www.bcg.com/about/about-bcg/net-zero

[19] Total. (n.d). Strengthening our presence in renewable energies. Retrieved 24 February 2021, from https://www.total.com/group/energy-expertise/exploration-production/renewable-energies/

[20] Shell. (n.d). Renewables and Energy Solutions (formerly New Energies). Retrieved 24 February 2021, from https://www.shell.com/energy-and-innovation/new-energies.html

[21] BP. (n.d). BP 2030 aims – low carbon electricity and energy. Retrieved 24 February 2021, from https://www.bp.com/en/global/corporate/what-we-do/gas-and-low-carbon-energy.html

Own reductions are incorporated into the carbon intensity equation. As all three companies aim to achieve net-zero by 2050, the remainder of emissions related to energy products supposedly has to be compensated for with external reduction methods as well.

Total Group is an extreme example of obscure reporting. The company avoids mentioning offsets but rather creates a new entity that funds, develops and manages activities that capture carbon naturally and ensures protection of ecosystems that already store high quantities of carbon emissions. By creating a separate section in its GHG emissions overview, labelled 'Scope 1 & 2 from operated oil and gas', emissions appear to decrease. However, emissions related to 'Integrated Gas, Renewable & Power, excluding upstream gas operations', which have risen from zero to three megatonnes of CO_2 equivalent between 2017 and 2019, are excluded from this section.

PetroChina is also remarkably untransparent about its near-zero emissions commitment. The company is assumed to utilise a similar strategy as the other oil and gas companies. PetroChina's assumed intensity targets and use of CCS are lower due to this lack of provided data.

Intensity targets and the used methodology to calculate reductions cause uncertainty. None of the oil and gas companies have targets approved by SBTi. Absolute reduction targets or statements saying oil exploitation will not be expanded would help in reduce uncertainty and increase accountability.

3.2. Impact assessment

The impact assessment quantifies the reduction potential of net-zero commitments. Datasets with different underlying assumptions are compared with each other and two reference scenarios. The sensitivity of the Impact Model, which calculates the Realistic Emissions, is tested. Findings are extrapolated to approximate the reduction potential of all companies with net-zero emissions commitments.

Forty-two unique companies are assessed in the Claimed Emissions and Realistic Emissions datasets. Except for PetroChina, all companies aim to achieve zero in or before 2050. EasyJet, PetroChina and Enel have only committed to reduce Scope 1 emissions, but this scope is by far the largest for all three companies.

3.2.1. Claimed Emissions and Realistic Emissions

The CAAT calculates annual emissions between 2015 and 2050 separately for the Claimed Emissions and Realistic Emissions datasets. Total Scope 1 emissions from the two datasets are fairly similar up until 2019 (Table 9). A larger difference, relative as well as absolute, can be observed in the summed Scope 2 emissions for 2019. This deviation is induced by the use of unbundled EACs, and to a lesser extent carbon offsets. Unbundled EACs are widely adopted in today's energy procurement strategies, causing a considerable difference in base year emissions due to their assumed low effectiveness. The difference in magnitude of the two scopes is attributable to companies with operations requiring little external energy inputs. Major contributors to Scope 1 emissions are energy utilities and fossil fuel companies but also transportation companies burning fuels to provide their services.

Table 9 - Total Emissions – Claimed vs. Realistic

	Scope 1	Scope 2
Total Claimed Emissions in 2019 [Mt CO_2 eq]	814	48
Total Realistic Emissions in 2019 [Mt CO_2 eq]	817	57
Total Claimed Emissions in 2050 [Mt CO_2 eq]	7	0
Total Realistic Emissions in 2050 [Mt CO_2 eq]	326	24
Claimed reduction between 2019 and 2050	99%	100%
Realistic reduction between 2019 and 2050	60%	58%

Total claimed Scope 1 emissions do not reduce to zero as PetroChina has a near-zero emissions commitment. Consequently, emissions of the 42 analysed companies reduce with 99% in 2050 compared to the combined emissions in 2019. All companies targeting Scope 2 emissions claim to reach zero in or before 2050. The few companies that do not target 100% RE procurement reduce the remainder with carbon offsets.

While the net-zero targets claim to reduce emissions to zero, realistic reductions, considering the ineffectiveness of utilised external reduction methods, do not reach zero. Total realistic Scope 1 emissions reduce with only 60% by 2050 compared to 2019. The decreased reduction is the result of assumptions about external reduction method effectiveness made in the Impact Model. Realistic Scope 2 emissions reduce even less. This implies that current energy procurement strategies have a lower expected relative effectiveness than the strategies formulated to reduce Scope 1 emissions for the companies analysed in the Impact Model. The outcomes also indicate that less than two-thirds of claimed reductions will be realised by the strategies in their current form. Scope 2 emissions are also expected to decrease due to lowering grid intensities, but this decrease cannot be ascribed to studied energy procurement strategies. Overlaps between energy utilities and companies are already incorporated in the remaining Scope 1 emissions in 2050 by the CAAT. Overlaps in realistic reductions are 73kt, while overlaps for claimed reductions are 105kt CO_2-eq. Both constitute less than 0.1% to the total reduction potentials.

To put the analysed emissions into perspective, global GHG emissions reached 52.4 gigatonnes (Gt) CO_2-eq in 2019 (Olivier & Peters, 2020). Before any market-based measures are applied, total combined Scope 1 and 2 base year emissions in the Realistic Emissions dataset make up about 1.7% of global GHG emissions. The studied companies' realistic reductions by 2050 would reduce current global GHG emissions by 1.0%.

Besides base year emissions and remaining emissions in 2050, the CAAT also calculates both datasets' emission trajectories. While the claimed the emissions under the net-zero targets of the sample would lead to zero by 2050 (dashed line in Figure 4), the realistic emissions under these targets do not reduce to zero (solid line in Figure 4). The realistic emissions are lower than the baseline (CPP in Figure 4) but would not be sufficient to follow a trajectory that would be needed to limit global temperature increase to 1.5°C (dotted line in Figure 4).

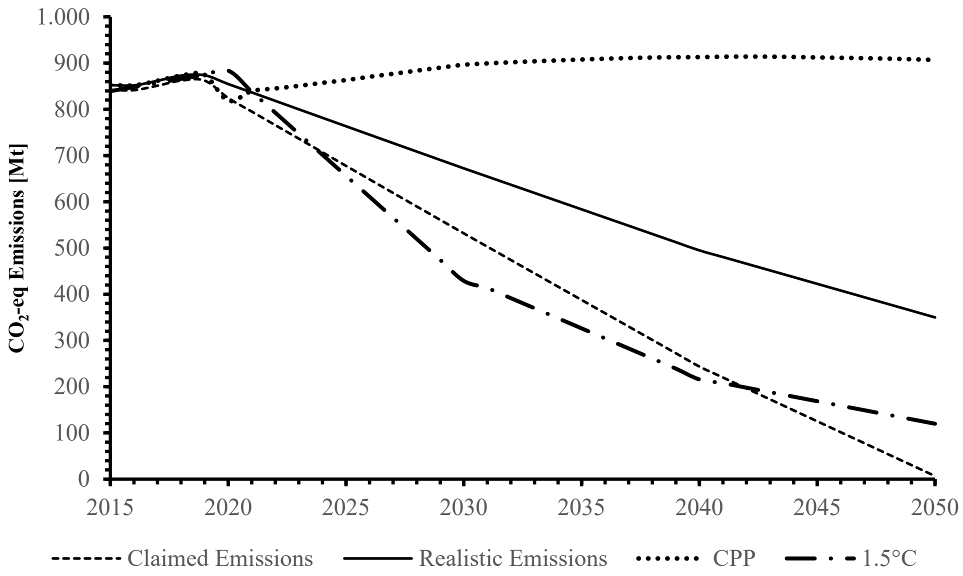

Figure 4 - Emission trajectories of combined Scope 1 and Scope 2 emissions of the compiled datasets with Current Policy Projections (CPP) and the 1.5°C mitigation pathway used as reference scenarios.

The emission trajectories are the sum of the 42 companies' annual combined Scope 1 and 2 emission reductions and depend on reduction targets and target years. The inclination of the trajectory indicates the average rate of reduction, the reduction rates of individual companies depend on their reduction targets and target years. Intermediate targets are incorporated in neither of the datasets due to complexity and time constraints. Inflection points in the emission trajectories are the result of net-zero commitments set prior to 2050. The emission trajectories appear practically linear because all companies currently emitting more than 10Mt CO_2-eq set targets for 2050. The only exception to this rule is RWE, a German multinational energy utility, which has a net-zero commitment for 2040. A minor inflection point is therefore observable in 2040 for both Claimed Emissions and Realistic Emissions trajectory in Figure 4.

Reference scenarios can be calibrated on only one dataset. The Claimed and Realistic Emissions trajectories already lie apart from the start because of the different interpretation of emission and reduction claims. As the reference scenarios are calibrated on the Realistic Emissions trajectory, the Claimed Emissions trajectory is not directly comparable to the reference scenarios, although the difference is small.

The decrease in emissions caused by the Covid-19 pandemic is already considered in the CPPs trajectory. This can be observed in the dip in emissions in 2020 and 2021 in Figure 4. Companies' emissions data is sourced from environmental reports which documented emissions up until 2019. Therefore, the dip in emissions cannot be observed in the compiled datasets and their emissions trajectories. According to the CAT, global GHG emissions stabilise between 2030 and 2050 in CPPs. Combined annual Scope 1 and 2 emissions in 2050 are 61% lower with the realistic reductions compared to CPPs, but a factor three higher than the 1.5°C pathway's emissions target for 2050.

The 1.5°C mitigation pathway limits global warming to 1.5°C throughout the 21st century with no- or limited- overshoot (IPCC, 2018). The quantified pathway derived from the CAT has not been updated with the ongoing pandemic's effects on emissions. The scenario's peak emissions for the century were expected in 2020. The 1.5°C mitigation pathway relies on an emission-reduction rate that is steeper than either trajectory of the studied datasets between 2020 and 2030. Some companies have set reduction targets that are in line with the 1.5°C pathway, but the datasets' average reduction rates are lower. The inclusion of intermediate targets would have added more detail to the emission trajectories. However, not all intermediate targets align with the 1.5°C mitigation pathway and some companies lack intermediate targets entirely.

Most companies in the Realistic Emissions dataset do not achieve net-zero. Whether these companies will continue reducing emissions after reaching their target year is not self-evident, as they have reached net-zero according to their own definitions. Further action to decrease the use of external reduction methods is optional. The net-zero claim is unaltered by these actions, providing little incentive for additional reductions.

3.2.2. Extrapolation

In phase two of data collection, a sample of 58 companies was randomly selected from the modified DDL dataset, which counts 1535 unique companies. An overview of the sample can be found in Appendix D. Eighteen of the analysed companies reported both a net-zero commitment and emissions, among them was BP, which was already analysed in the first phase of data collection. The analysed companies are part of the 42 companies included in both datasets and were assessed in the Impact model. To prevent double counting, BP is included only once.

The publicly available documents of the analysed companies often did not include emissions or an explicit net-zero commitment. Emissions data was unavailable for 34 of the sample's listings. Some listings turned out to be subsidiary companies of larger corporates, others could not be found online. Companies such as Anko, a subsidiary retail chain of Australian Wesfarmers, and Danone Waters Germany, a subsidiary of French Danone Group, do not report emissions separately. Many of the sampled companies are B Corporations, which are for-profit companies with certification of social and environmental performance. The relatively small size of many B Corps limits their online presence and environmental reporting capacities. The majority of B Corps are presumably included in the DDL dataset because they are member of the B Corp Climate Collective[22]. This initiative collaborates with UNFCCC's Race to Zero campaign. Participants of the campaign have until COP26, which will be held in November 2021, to come up with a reduction strategy (UNFCCC, 2020a).

Six companies reported emissions but did not make an explicit net-zero commitment, as can be seen in Table 10. Their Scope 1 and 2 emissions sum to almost forty megatonnes, which makes up 19% of the sample's total reported emissions.

[22] Net-zero Climate. (n.d). Net-zero 2030 — B Corp Climate Collective. Retrieved 19 February 2021, from https://www.netzeroclimate.org/net_zero_tools/2019_b_corp_climate_collective/

Table 10 - Sample properties

Companies analysed	58
Net-zero commitment: yes	20
Net-zero commitment: no	38
Net-zero commitment & reported emissions	18
No net-zero commitment, but reported emissions	6
Emissions covered with net-zero commitments [Mt CO_2 eq]	167
Emissions without net-zero commitments [Mt CO_2 eq]	40
Combined total [Mt CO_2 eq]	206

The eighteen companies meeting both requirements were further analysed. Combined Claimed Emissions and Realistic Emissions both slightly deviate (<1%) from emissions covered with net-zero commitments, depicted in Table 11. Deviations are caused by interpretations of neutrality and RE claims.

Table 11 - Sample's emissions covered with net-zero commitments – Claimed vs. Realistic

	Scope 1	Scope 2	Combined
Total Claimed Emissions [Mt CO_2 eq]	159	6.6	166
Total Realistic Emissions [Mt CO_2 eq]	159	7.4	167
Remaining Claimed Emissions [Mt CO_2 eq]	0	0	0
Remaining Realistic Emissions [Mt CO_2 eq]	26.8	2.7	29.5
Claimed reduction	100%	100%	100%
Realistic reduction	83%	63%	82%

Similar to the Impact Model findings of all 42 companies, realistic Scope 2 reduction strategies underperform compared to their Scope 1 counterparts. The majority of emissions is once again accounted for in Scope 1. The sample's realistic reductions are more effective than the Realistic Emissions dataset's average reductions.

The sample is extrapolated with the help of a multiplication factor. The factor derived by dividing the total of modified DDL dataset listings *(population=1535)* by the sample size *(=58)*. The multiplication factor of 26.47 is used to approximate the modified DDL dataset's total emissions and potential reductions. The extrapolation's outcome is presented in Table 12.

Table 12 - DDL emissions covered with net-zero commitments – Claimed vs. Realistic

	Sample	DDL	Reduction potential (from total reported emissions)
Total reported emissions (with and without net-zero commitment) [Mt CO_2 eq]	206	5,460	
Total Claimed Reductions [Mt CO_2 eq]	166	4,390	80%
Total Realistic Reductions [Mt CO_2 eq]	137	3,630	67%

According to the extrapolation, approximately 5.5Gt of GHG emissions is emitted by companies included in the modified DDL dataset, which is roughly ten percent of global GHG emissions for 2019. 900 of the 1535 listings are expected to be excluded due to unavailable emissions data. Based on the sample's performance, claimed net-zero commitments reduce 80% of total reported emissions by 2050. The remaining 20% is likely to shrink in size as well but is currently not covered by net-zero commitments. Based on the extrapolation, the current realistic reduction potential of all net-zero emission commitments included in the modified DDL dataset is approximately 3.6Gt. With CPP, CAT expects 53.8Gt of global GHG emissions by 2050. The extrapolated reduction potential decreases this projection by almost seven percent, assuming none of the reductions are factored in CPP already.

3.2.3. Reductions per sector

Companies in the Impact Model were categorised into sectors (Appendix E) to assess average sector performance. Table 13 displays Scope 1 and 2 emissions and reductions per sector, where *n* represents the number of companies analysed per sector.

Table 13 - Average sector performance

	Scope 1 emissions [kt CO_2 eq]	Scope 2 emissions [kt CO_2 eq]	Scope 1 reductions	Scope 2 reductions	Total reductions
Transport *(n=4)*	20,300	261	56%	26%	56%
Heavy industry *(n=2)*	117,000	5,550	72%	32%	68%
Fossil fuels *(n=4)*	72,400	4,700	38%	72%	40%
Apparel *(n=3)*	10	220	70%	63%	63%
Energy *(n=4)*	50,200	1,230	82%	89%	82%
Finance *(n=3)*	6	40	51%	21%	25%
Telecom / Internet *(n=7)*	84	733	83%	73%	74%
Manufacturing *(n=10)*	564	735	66%	31%	46%

Average proportions of Scope 1 and 2 emissions vary considerably among sectors. The transport sector emits substantially more Scope 1 emissions while the apparel industry's emissions mainly result from energy procurement. On average, heavy industry pollutes most emissions in both scopes. Net-zero commitments of the energy and telecom sectors turn out most robust. Heavy industry nonetheless reduces most emissions per company in absolute terms. Transport and fossil fuel companies form the largest potential to improve absolute realistic Scope 1 reductions.

The finance industry's underwhelming performance is related to the target years of their net-zero commitments. All three commitments are due in this decade, giving the companies little time to transform their operations. The reductions strategies rely on legal instruments to quickly achieve net-zero. A green image is one of few options for financial companies to set themselves apart from their competition.

3.2.4. Sensitivity analysis

Input parameters

All deviations made to test the sensitivity of input parameters lie within the realistic ranges used for the Monte Carlo Simulation, which is discussed later. An overview of the used ranges is found in Appendix B. The effects of input parameters are measured on base year emissions and target year reductions for both scopes. Reduction targets are more sensitive to changes in input parameter values than base year emissions, as was expected. One noteworthy influence on base year emissions is the assumed use of carbon offsets for Scope 1 in the base year. Increasing this parameter from zero to five percent increases Scope 1 base year emissions by 1.3Mt, although this is only a 0.16% increase from original total Scope 1 emissions.

The Impact Model behaves fairly robust. Input parameter changes of five percentage points only once affected output values by more than five percent (Table 14). Total Scope 2 emission reductions decrease by 5.6% when companies are assumed to address five percent of their energy procurement strategy with offsets rather than energy efficiencies. 5.6% of total Scope 2 reductions is roughly 1.8Mt of GHG emissions.

Table 14 - Total target year reductions sensitivity to input parameters

		Scope 1 - relative	Scope 2 - relative	Scope 1 – absolute [kt CO_2 eq]	Scope 2 – absolute [kt CO_2 eq]
Electricity procurement – effectiveness					
Unbundled EAC		0.0%	2.2%	0	729
PPA		0.0%	2.3%	0	740
On-site		0.0%	1.1%	0	372
Combination					
Offsets – effectiveness					
Natural sequestration		3.0%	0.1%	14,700	15
Avoided emissions		0.1%	0.0%	459	5
Direct air capture		0.0%	0.0%	1	0
CCS		1.2%	0.0%	6,100	0
Emission reduction strategy in case unclear					
Use of RE in base year		0.0%	0.2%	0	57
Use of RE in target year		0.0%	4.4%	0	1,450
Use of RE with target in this decade		0.0%	0.1%	0	40
Scope 1 offsets in base year		0.3%	0.0%	1,270	0
Scope 2 offsets in base year		0.0%	0.8%	0	255
Scope 1 offsets in target year	low	0.1%	0.0%	571	0
	medium	0.1%	0.0%	240	0
	high	1.3%	0.0%	6,440	0
Scope 2 offsets in target year		0.0%	5.6%	0	1,820
Unbundled EAC use in base & target year		0.0%	1.2%	0	392
Natural offset use in base & target year		0.0%	0.0%	4	0

In absolute terms, the Impact Model is most sensitive to deviations in the effectiveness of natural sequestration offsets. If natural sequestration offsets have no impact at all, rather than the assumed five percent effectiveness of what is claimed, Scope 1 emission reductions decrease by almost 15Mt. Scope 1 emission reductions decrease by 6Mt when either CCS is five percent less effective or companies in the 'high' category use offsets for 60%, rather than 55%, to reach their net-zero target. Only seven companies make use of CCS for their reduction strategy, and only two fall in the 'high' category without specifying offset types. Yet absolute Scope 1 emission reductions deviate considerably due to changes in these two input parameters. The sensitivity is caused by the size of these companies' Scope 1 base year emissions.

Effectiveness based on price and use based on sales

The 14% realistic effectiveness for natural sequestration offsets, derived by taking their price relative to the price of EU permits, is almost three times as high as the original value. Avoided emissions offsets' decrease in effectiveness based on price does not compensate for the increase in reductions caused by natural sequestration offsets. Many companies select and are assumed to select natural sequestration projects when purchasing offsets. The substantial use of natural sequestration offsets makes the model sensitive to adaptations in effectiveness.

By basing input parameter effectiveness on relative prices, the Realistic Emissions dataset's total Scope 1 reductions increase by 27Mt. This is a 5.5% increase over the original reductions. Scope 2 reductions decrease by 1.2Mt due to decreased effectiveness of unbundled EACs.

The revisited allocation of offset types for companies that are untransparent about their use of offsets has a negligible effect on model outcomes. Many large polluters have indicated their preference for natural sequestration offsets, their reduction strategy therefore is unaltered by changes in assumed allocation.

Considering the low offset prices, increased competition for land and limited potential for permanent carbon storage of natural sequestration, I assume the maximum realistic effectiveness for natural sequestration offsets to be seven percent. The effectiveness based on relative prices surpasses this maximum, resulting in significant deviations from the original outcome and the Monte Carlo Simulation.

Intensity targets

Total Group aims to reduce the carbon intensity of its operations by 60% in 2050. The original absolute reduction target in the Impact Model therefore depends on offsets for 70%. When interpreting the intensity targets of fossil fuel companies as absolute reduction targets without halving it first, the dependence on offsets decreases to 40%. The same is done for PetroChina's, BP's and Shell's intensity targets.

As a result, absolute Scope 1 emission reductions of the entire Impact Model increase by more than ten percent. An additional 50Mt of GHG emissions are reduced by this different interpretation of intensity targets. On the one hand, the increase in reductions highlights the potential of ambitious reduction strategies by the fossil fuels industry. On the other hand, the uncertainty caused by expressing intensity targets rather than absolute reduction targets becomes apparent.

Monte Carlo simulation of Impact Model

A Monte Carlo simulation is used to model the probabilities of the Impact Model's outcomes based on the realistic ranges for input parameters defined in Appendix B. By performing a multitude of random iterations, where the input parameters are allowed to vary freely among the defined ranges, the simulation develops a distribution of outcomes (Mooney, 1997). Through the simulation, the boundaries of the model become clear, and the likeliness of the original outcome can be assessed.

Table 15 - Monte Carlo Simulation outcome– 10,000 iterations

	Scope 1 emissions [Mt CO2 eq]	Scope 2 emissions [Mt CO2 eq]	Scope 1 reductions [Mt CO2 eq]	Scope 2 reductions [Mt CO2 eq]	Combined reductions [Mt CO2 eq]
Original	818	57	492	33	525
Mean	817	57	487	29	515
Standard deviation	0.9	0.6	10.0	2.4	10.3
Minimum	814	55	458	21	478
Maximum	818	59	515	35	551
Minimal reduction potential			56%	36%	55%
Maximal reduction potential			63%	64%	63%
Mean reduction potential			60%	50%	59%
Original reduction potential			60%	58%	60%

The Impact Model behaves robustly considering the low standard deviations. The largest deviation is measured in Scope 2 reductions where the lowest outcome differs 27% from the mean. It was already observed that the Impact Model does not behave too sensitive to individual input parameter changes. The simulation shows that input parameters do not strongly reinforce each other within the set ranges.

The minimal realistic reduction potential is derived by dividing the minimal reductions by the maximal base year emissions. The opposite is done to calculate maximal reduction potentials. Combined Scope 1 and 2 base year emissions will be reduced at least 55% by 2050 when all companies execute their mitigation strategies in their current form.

The use of unbundled EACs and PPAs make up a larger fraction of energy procurement strategies compared to the relative dependence of offsets and CCS to reduce Scope 1 emissions. Changes in effectiveness of external reduction methods thus result in higher uncertainty in Scope 2 emission reductions.

The simulation's distribution of Scope 1 emission reductions is depicted in Figure 6. The original outcome is marked in orange. The outcome is considered probable due to its low deviation from the mean of the simulation.

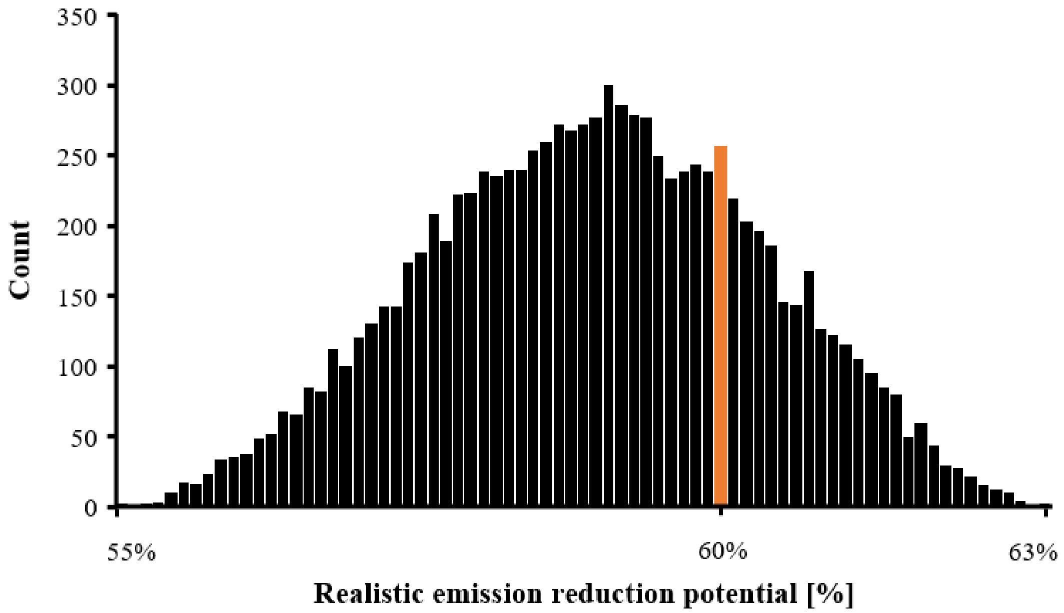

Figure 5 - Distribution (n=10,000) of realistic combined Scope 1 and 2 emission reductions in 2050 compared to 2019, calculated by the Impact Model. Original Impact Model outcome is marked orange.

Extrapolation significance

Assuming the DDL dataset yields a continuous normal distribution of 1535 emissions, a sample of 308 listings is required to reach a 95% confidence level with a margin of error of 5%. Even more listings need to be analysed if the data does not follow a normal distribution.

The DDL dataset likely does not follow a normal distribution considering the presence of many listings without reported emissions. Moreover, three out of eighteen companies fulfilling both requirements for inclusion in the Impact Model, together emit 98% of this sample's total Scope 1 emissions. Therefore, the reduction potential primarily depends on these three companies.

I am not fully confident (<90%) that the extrapolated outcomes can be replicated within a 5% margin with the current sample size of 58 listings. The sample size needs to increase to meaningfully extrapolate findings to the whole DDL dataset. This limitation does not alter findings for individual companies and trends observed between sectors in the Impact Model.

4. Discussion

This study's assessment of the emission reduction potential hinges on the assumed use and effectiveness of external reduction methods. The analysed mitigation strategies, especially those of companies in hard-to-abate sectors, often comprise a substantial number of offsets and EACs. Considering the ineffectiveness of external reduction methods in net-zero commitments, 40% of claimed emission reductions does not materialise. Studies towards commitments that do not consider the quality of mitigation strategies, are therefore likely to overestimate their potential for emission reductions. A study on request of the EU Commission suggests that 85% of sold voluntary offsets from the UN's Clean Development Mechanism (CDM), the largest offsetting scheme globally, are likely overestimated and not additional (Cames et al., 2016).

The market for voluntary carbon offsets is expected to grow substantially over the coming decades and, at the same time a shift towards natural sequestration projects is observed in this market (Ecosystem Marketplace, 2019). Its extensive use makes natural sequestration effectiveness, which is assumed exogenously, an influential variable for assessing commitments' quality. Multiple uncertainties in estimating emission reduction effectiveness of forestry projects exist. Soil conditions, regional climate, tree species, occurrence of fires and droughts and land use change have to be considered (Gössling et al., 2007).

According to Fuss et al. (2018), the annual sequestration potential of afforestation and reforestation projects for 2050 is approximately 6Gt CO_2-eq emissions, which is roughly one-tenth of current global anthropogenic emissions. The average net-zero commitment depends on more than these natural sequestration offsets. Hence, net-zero commitments take up an unfair share of relatively easy and cheap emission reductions or the effectiveness per offset is overestimated, or both.

I consider the relative price of natural sequestration offsets compared to EU ETS permits, as taken in the sensitivity analysis, to be an inadequate proxy for effectiveness. Forestry offsets enjoy a green image as nature sells well to the public. This green image and a limited supply in offsets likely inflate the selling price. The performance of the EU ETS with its current amount of permits in circulation also is not aligned with the emission reduction target of the Paris Agreement (European Commission, 2020). A decrease in supply, thus increase in price is required, and this makes the current permit price an imperfect indicator for the real cost of reducing emissions.

The share of unbundled EACs in Scope 2 mitigation strategies is even larger than the share of natural sequestration offsets to address Scope 1 emissions. This renders unbundled EACs another influential variable in assessing the commitments' quality. EACs can be bought for as little as 10 eurocents per megawatt-hour but are allowed by SBTi to compensate for energy procurement emissions with the market-based accounting method. Companies can also buy EACs for a higher price to support local RE projects, the effectiveness of EACs therefore likely varies. Checking what type of EACs a company buys and for what price is currently impossible. Therefore, the average EAC is assumed to have a low effectiveness. In regions where a residual mix factor is not utilised to calculate location-based emissions, cheap EACs probably do not even reach the assumed effectiveness of ten percent as the reductions are already accounted for in the average grid intensity, while the minimal and uncertain price provide little incentive to invest in new RE projects. Although some uncertainties around the use and effectiveness of external reduction methods remain, I am confident that the model's outcomes are in the right order of magnitude. This confidence is supported by the Monte Carlo Simulation

Companies use several terms to commit themselves to nullify effects on the surrounding climate. Realistic reductions for 'net-zero commitments' are relatively high compared to 'neutrality' targets, but as the latter have shorter time horizons to bring about change, they are not inferior per se. After correcting for the use of external reduction methods, the annual reduction rate of targets with shorter time-horizons is actually higher, even if the emission level reached at the endpoint is higher. The more a company approaches zero however, the more difficult and expensive emission reductions are expected to become. As total reductions of short-term targets are lower, the impact of external reduction methods is more prominent.

Companies paying little attention to own emission reductions have to purchase external reduction methods indefinitely. The quality of these external reduction methods must withal improve annually to maintain the annual reduction rate after reaching the target. Whether companies will continue reducing emissions after reaching their commitment is not self-evident. Reputation is an important driver for participating in climate mitigation efforts (Hirsch, 2019). Net-zero and neutrality claims are unaltered by additional actions and this thus provides little incentive to further increase ambitions.

Net-zero commitments by fossil fuel companies, aviation companies and to a lesser extent heavy industry are not the most transparent reflection of these industries' prospects. Even though positive steps are being taken to improve efficiencies and to invest in large scale RE projects, sustainable fuels, and carbon capture and storage projects, a substantial amount of residual emissions remains and is addressed with external reduction methods with low effectiveness. These companies do not have to be discouraged from making net-zero or neutrality claims per se, but it should become very clear what can be expected of them. Transparency about the amount and type of external reduction methods utilised in the mitigation strategy is required to make an assessment of the quality of commitments. My assessment informs policy makers to introduce new legislation, if necessary, to align commitments with the 1.5°C mitigation pathway. External reduction methods can still help achieve emission reductions, but I advise to follow the Oxford principles for net-zero aligned carbon offsetting to ensure additionality (University of Oxford, 2020).

The realistic emissions resulting from the analysed net-zero commitments fall short of the 1.5°C mitigation pathway in their current form. The total emission trajectory of the dataset is strongly influenced by a few companies with substantial emissions. The mitigation strategies of these companies determine the total reduction potential of the dataset to a great extent. As fossil fuel companies, heavy industry and energy utilities annually emit tens of megatonnes of CO_2 equivalent, emissions are often rounded to the nearest hundred kilotonnes. As emissions of companies in finance and the clothing industry are often below a hundred kilotonnes in total, the mitigation strategies of these companies are rendered negligible to my study's average emission trajectory. The cumulative impact of companies in less polluting industries can still be substantial, and ambitious net-zero commitments provide an example to others. However, the influence of companies in hard-to-abate sectors on global emissions and the generally poor quality of their net-zero commitments highlights the importance to direct policy efforts to these sectors.

The 1.5°C mitigation pathway does not follow a straight line. More than half of all emission reductions until 2050 occurs before 2030. Approximately half of the analysed companies has intermediate targets aligned with the 1.5°C pathway that are verified by SBTi. The detail of the emission trajectory would improve when latest inventory year emissions and intermediate targets are included in the aggregation tool. Due to time limitations, a consideration between incorporating extra data into the model and an expansion of the analysed sample was required. Trends become easier to observe and confidence in the outcome increases when more companies are included in the study. I prioritised the sample size, as I think this has a bigger impact on my study's outcome.

In both the quality assessment and the impact assessment, reductions of a company's own emissions receive little attention. Scope 1 and 2 emission reductions achieved without the use of external reduction methods are assumed to result from energy efficiencies, electrification and on-site generation of, less carbon intensive, energy. If a company outsources activities, sells off carbon intensive subsidiaries or generally shrinks in size, the Impact Model would falsely attribute the emission reductions to own reductions with 100% effectiveness. More transparency about companies' emission sources enables auditors to account for these developments. The difficulty to grasp these meaningless emission reductions also emphasise the importance to develop sector-wide standards. When activities are transferred to another company, the carbon intensity per unit of produced good or service should not increase. When a company shrinks in size at the expense of another company, this other company should be incentivised to uphold the same, or a more stringent, emission mitigation strategy as the company it replaces.

Company growth is also not captured by the Impact Model. However, any additional emissions need to be addressed regardless, as companies set absolute reduction targets that go to zero. When companies set intensity targets, these are transformed to absolute reduction targets where growth is taken into account. Energy consumption of companies in the telecom and tech sectors could increase dramatically over the coming years, while aircraft activity is expected to grow as well. When these additional emissions are addressed with ineffective market-based solutions, absolute emissions still increase. On the other hand, the global transition towards energy with a lower grid intensity factor also is not captured by the model. The importance of growth and the decreasing grid intensity factor differs per industry and region but work in opposite direction. The net effect on global emissions depends on the effectiveness and use of external reduction methods and the speed of the energy transition.

For some sectors, Scope 3 emissions transcend Scope 1 and 2 emissions, but they are omitted from the Impact Model (Hertwich & Wood, 2018). Scope 3 emissions are prone to be accounted for by multiple entities and companies have less control over them. Some net-zero commitments do include Scope 3 emissions and effective methods exist to reduce emissions in the supply chain. Considering the possible accounting errors, Scope 3 emissions are excluded from my quantitative assessment of net-zero commitments. A model that focusses on the activities where these emissions occur is better suited to make this assessment. As the focus of such a model shifts away from companies with net-zero commitments, its development lies outside the boundaries of my study.

My assessment shows that mitigation strategies to achieve net-zero commitments differ among sectors. The observed trends are based on a limited dataset and analysing more companies would enhance precision. In the first phase of data collection, reputable companies pioneering in respect to climate efforts were selected. These influential companies are among the best performers in their industries. The average emission reduction potential of current mitigation strategies in an industry is therefore unlikely to be higher than the realistic reduction potential of the analysed companies in those industries.

5. Conclusions

This study analysed publicly available data about companies' greenhouse gas emissions and climate action strategies to assess the reduction potential of net-zero emission commitments. I focus specifically on companies, as they have made modest climate contributions thus far and often have ulterior motives due to their profit maximizing character. Forty-two companies' net-zero commitments were assessed with a quantitative assessment, where qualitative aspects of emission mitigation strategies were considered. My study bridges earlier research towards the potential of net-zero claims and separate research towards the quality of such claims. The setup of my study was guided by two research questions:

RQ1 – What is the quality of current net-zero emission commitments by companies considering their target definition and mitigation strategies?

The analysed net-zero commitments vary in quality due to differences in transparency and the use of external reduction methods. Although the sample size is relatively small, clear trends can be distinguished among sectors. Energy and telecom companies focus on own emissions, while companies in the transport, fossil fuels and finance industry resort to a larger extent to carbon offsets. Transport, heavy industry, and manufacturing companies also make abundant use of energy attribute certificates to compensate for emissions relate to energy consumption.

The use of external reduction methods significantly reduces the realistic emission reduction potential of net-zero commitments. Only two companies claim to refrain from the use of offsets to reach net-zero altogether. 40% of analysed companies does not mention the use of offsets in its public documents. Many of the companies that do mention offsets in their reduction strategies do not specify their price or origin, let alone their relative importance to reach the target. The same is observed for unbundled energy attribute certificates. These certificates are used to make renewable energy claims while they have negligible influence on the realisation of new renewable energy projects. Considering the limited additionality of offsets and certificates, their abundant use deteriorates the quality of net-zero commitments.

Commitments are also difficult to compare due to the various terms that are used interchangeably. On average, commitments aiming for carbon, CO_2 or climate neutrality *(n=18)* are due eight and a half years earlier than net-zero commitments *(n=21)*. The latter also achieve higher reductions for both Scope 1 *(71%>59%)* and Scope 2 *(54%>35%)* emissions compared to the former. Although terms are used interchangeably by some companies, net-zero generally refers to more ambitious commitments with longer time horizons. However, the realistic reduction potential of targets set in 2040 is higher than those set in 2050. This implies that mitigation targets set in a too distant future are postponing transformation without further improving the mitigation strategy. Companies with targets in 2040 have robust mitigation strategies that prioritise emission reductions through improving efficiencies. Commitments for 2030 and earlier generally rely more on ineffective external reduction methods, but a few companies realise remarkable reductions as well. These companies operate in innovative and relatively easy-to-abate industries or address emissions with market-based instruments of high quality.

RQ2 - What is the emission reduction potential of net-zero emission commitments by companies considering their quality?

Considering the quality of current mitigation strategies, combined annual Scope 1 and 2 emissions of the analysed 42 net-zero commitments reduce from approximately 881Mt of greenhouse gas emissions in 2019 to 350Mt in 2050. In other words, ambitious companies with net-zero commitments reduce emissions by only 60% of what they claim, as the effectiveness of the majority of external reduction methods is likely overestimated.

The analysed sample's base year emissions cover roughly 1.7% of global greenhouse gas emissions in 2019. Compared to current policy projections for 2050, my impact assessment expects the analysed net-zero commitments to reduce emissions by 61%. However, the remaining emissions in 2050 are still a factor three higher than the emissions target to limit global warming to 1.5°C. If the net-zero commitments are to be in line with a 1.5°C pathway, their emission mitigation strategies thus must be improved.

Outlook

The objective of my study is to understand the extent to which net-zero commitments actively support a transition towards deep decarbonisation, and whether intervention is required to achieve this transition. Although the analysed companies belong to the most ambitious of their industries and some make real strides to reduce emissions, my study reveals that current efforts are not enough.

Several companies in hard-to-abate sectors have set untransparent targets. Emission reduction strategies are unclear, and assumptions had to be made about the use of external reduction methods. One could be suspicious that companies, especially those in hard-to-abate sectors, are incentivised to set net-zero commitments to maintain a green and cooperative reputation. Such an image can help them convince the public and avoid more stringent climate regulation by governments. As a result, it can be wrongfully assumed that emissions will be reduced while polluters can be held limitedly accountable. If these companies increase transparency around emissions and mitigation strategies, one could no longer be suspicious. Increased transparency can also improve insight, accountability and consequently ambition. The quality assessment shows that targets that are verified by the Science Based Targets initiative (SBTi) have higher realistic reductions. Emissions should be reported according to the Greenhouse Gas Protocol to improve understanding of actors' control over emissions, while progress can be measured against intermediate targets.

Since companies' own emission reductions have a more certain impact and are necessary in any case, they should be prioritised over market-based measures from a quality perspective. Reducing energy consumption will always be more effective than consuming energy from the least polluting sources. However, emissions in hard-to-abate sectors such as heavy industry, fossil fuels and aviation will likely be difficult to eliminate entirely by 2050.

Right now, heavy industry and manufacturing predominantly address Scope 2 emissions with unbundled energy certificates. Since energy consumption in these industries is clustered, a shift to on-site renewable energy generation and long-term contracts with local energy utilities can improve the reduction potential of these companies' energy procurement strategies. The aviation sector and the fossil fuels industry both plan to utilise offsets to address their residual Scope 1 emissions. A public registry where origin and price are reported for retired offsets can improve insight. Permissible offsets should be of high quality, such as described by the Oxford Principles for Net Zero Aligned Carbon Offsetting (2020). A shift away from external reduction methods with a high risk of non-additionality and reversal is necessary to bring net-zero commitments in line with an emission pathway that limits global temperature to 1.5°C.

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7. Appendices

Appendix A - Quality assessment template

Question	Explanation
Company information	
Name of company	
Country where HQ is located	
Number of employees	
Revenue	
Sector	
GHG emissions information	
Base year emissions	The emissions in the base year, the year from which emissions reductions are measured [Mt CO2e] – divided in Scope 1, 2 & 3
Base year	The year from which emissions reductions are measured
Total GHG emissions	The most recent emissions data available [Mt CO2e] – divided in Scopes 1, 2 & 3
Total GHG emissions year	The most recent year of emissions data available
Net-zero target information	
Target terminology	What term does the company use to describe its target?
Target year	The target year in which the emissions reductions will be accomplished
Pollutants included	Which pollutants are covered by the net-zero target? *(e.g., only CO2 or all GHG emissions)*
Net-zero scope	Scopes included by net-zero target
Includes interim targets	Any emission reduction commitments made prior to the net-zero commitments
Information on approaches to achieve the target	
Strategic plan	Does the actor have a plan to achieve its target?
Planning process	Was there some planning exercise / stakeholder process within the organisation for determining the target?
Own reductions	
Own reductions - Scope 1	The actor plans to reduce own emissions through operational measures (Scope 1)
Own reductions - Scope 2 - activity reduction	The actor plans to reduce own emissions through operational measures (Scope 2 - through activity reduction)
Own reductions - Scope 2 - on-site RE	The actor plans to reduce own emissions through operational measures (Scope 2 - installing on-site RE)
Own reductions - Scope 3 - upstream	The actor plans to reduce own emissions through operational measures (Scope 3 upstream - business travel, activity reduction, supplier adaptation)
Own reductions - Scope 3 - downstream	The actor plans to reduce own emissions through operational measures (Scope 3 downstream - support for customers to consume less / more efficiently / use of products)
Percentage of own reductions	What share of the net-zero target will be reduced through own emission reductions?
Mt own reductions	By how many Mt does the actor plan to reduce its own emissions (can be per year or total)
Electricity procurement	
Electricity procurement	Does the actor plan to reduce Scope 2 emissions? If so, how?
Percentage or amount of electricity procurement	What do they claim in terms of the reduced GHG impact of the energy procurement approach? I.e., x% reduction of energy emissions; x% reduction of *all* (Scope 1, 2, 3) emissions; other claims?
Offset credits	
Offset credits	Does the actor plan to use offset credits
Share of offset credits	What share of the net-zero target will be reduced through offset credits?
Mt offset credits	How many Mt does the actor plan to offset (can be per year or in total; may also change over the years)
Offset type	What type of offset credits does the actor plan to use?
Importance avoided & reduced / natural / direct air capture	If both multiple types of offsets, what is their relative importance now or in the future?

Price per offset	What price does the company pay per offset credit?
Investing in removals	Does the actor invest in removals (other than offsets) and does it claim those gains towards its target? / Does the actor make funds available for emission mitigation without claiming gains towards own target?
Other	
Separate target for removals and reductions	Does the actor have separate targets for emission reductions and removals?
Contribution claim	If the actor purchases offset credits / RE certificates, do they use these to claim a contribution to emission reductions/removals elsewhere? (or towards own target / no claim at all)
Other – company specific	*e.g., tables and graphs*

Appendix B - Input parameters - assumed realistic ranges

		Original value	Minimum	Maximum
Electricity procurement - effectiveness				
Unbundled EAC		10%	0%	10%
PPA		80%	60%	85%
On-site		100%	90%	100%
Offsets - effectiveness				
Natural sequestration		5%	0%	7%
Avoided emissions		10%	0%	10%
Direct air capture		100%	85%	100%
CCS		85%	80%	90%
Emission reduction strategy in case unclear				
Use of RE in base year		20%	0%	30%
Use of RE in target year		80%	70%	90%
Use of RE with target in this decade		95%	90%	100%
Scope 1 offsets in base year		0%	0%	10%
Scope 2 offsets in base year		0%	0%	10%
Scope 1 offsets in target year	low	15%	5%	25%
	medium	35%	25%	45%
	high	55%	45%	65%
Scope 2 offsets in target year		0%	0%	10%
Unbundled EAC use in base & target year		95%	85%	100%
PPA use in base & target year		(100% - unbundled EAC)		
Natural offset use in base & target year		100%	80%	100%
Avoided emissions use in base & target year		(100% - Natural offsets)		

Appendix C - Overview answers to quality assessment

Company	Target terminology	Interim targets	Final target year	SBTi member	1.5 °C ambition	Plans to use offsets	Scope included in target
Boston Consulting Group	Net zero emissions	Yes	2030	Yes	Yes	Yes	Scope 1, 2 & partly 3
Velux	Carbon neutral	Yes	2030	Yes	Yes	Unclear	Scope 1, 2 & partly 3
Apple	Carbon neutral	No	2030	No		Yes	Scope 1, 2 & 3
Amazon	Net zero emissions	Yes	2040	Yes	No	Unclear	Unclear
Vodafone	Net zero emissions	Yes	2030	Yes	Yes	Yes	Scope 1, 2 & 3
Sky	Net zero emissions	No	2030	Yes	Yes	Yes	Scope 1, 2 & 3
IAG	Net zero emissions	Yes	2050	Yes	Yes	Yes	Scope 1 & 2
Total	Net zero emissions	Yes	2050	No		Unclear	Scope 1 & 2
Adidas	Climate neutral	Yes	2050	Yes	No	Yes	Scope 1 & 2
H&M	Other	Yes	2040	Yes	Yes	Unclear	Scope 1, 2 & 3
EasyJet	Carbon neutral	No	2020	No		Yes	Scope 1
Siemens	Carbon neutral	No	2030	Yes	Yes	Yes	Scope 1 & 2
Maersk	Net zero emissions	Yes	2050	Yes	No	No	Scope 1 & 2
ArcelorMittal	Carbon neutral	Yes	2050	No		Unclear	Unclear
HeidelbergCement	Carbon neutral	Yes	2050	Yes	No	unclear	Scope 1, 2 & 3
PetroChina co	Other	Yes	2050	No		Unclear	Unclear
BP	Net zero emissions	Yes	2050	No		Yes	Scope 1, 2 & partly 3
Philips	Carbon neutral	Yes	2040	Yes	Yes	Yes	Scope 1, 2 & partly 3
Microsoft	Other	Yes	2030	Yes	Yes	Yes	Scope 1, 2 & 3
Novo Nordisk	Net zero emissions	Yes	2030	Yes	Yes	Unclear	Scope 1, 2 & partly 3
SAP	Net zero emissions	Yes	2050	Yes	Yes	Yes	Scope 1, 2 & partly 3
RWE	carbon neutral	No	2040	Yes	No	Yes	Scope 1
Volkswagen	carbon neutral	Yes	2050	Yes	No	Yes	Scope 1, 2 & partly 3
DHL	Climate neutral	Yes	2050	Yes	No	Yes	Scope 1
Shell	Net zero emissions	Yes	2050	No		Yes	Scope 1 & 2
OP Financial Group	Carbon neutral	No	2025	No		Unclear	Scope 1 & 2
SingTel	Net zero emissions	Yes	2050	Yes	No	Unclear	Unclear
Tendam	Net zero emissions	Yes	2050	Yes	Yes	Unclear	Scope 1 & 2
Church & Dwight	Carbon neutral	No	2025	No		Yes	Scope 1, 2 & 3
Husqvarna AB	Net zero emissions	Yes	2050	Yes	Yes	Unclear	Scope 1, 2 & 3
Enel	Net zero emissions	Yes	2050	Yes	Yes	No	Scope 1

continued							
Company	**Target terminology**	**Interim targets**	**Final target year**	**SBTi member**	**1.5 °C ambition**	**Plans to use offsets**	**Scope included in target**
Godrej CP - India	Carbon neutral	No	2020	Yes	No	Yes	Scope 1 & 2
Yarra Valley Waters	Net zero emissions	Yes	Already achieved (for 11yrs) - new target 2025	Yes	Yes	Yes	Scope 1 & 2
Southampton Airport	Carbon neutral	Yes	2030	No		Yes	Scope 1, 2 & 3
MetLife	Carbon neutral	Yes	already achieved, new target 2030	Yes	No	Yes	Scope 1, 2 & partly 3
NRG Energy	Net zero emissions	Yes	2050	Yes	No	Unclear	Scope 1, 2 & partly 3
STMicroelectronics	Carbon neutral	Yes	2027	Yes	Yes	Yes	Unclear
TDC A-s	Carbon neutral	Yes	2028	Yes	Yes	Unclear	Scope 1 & 2
Centrica	Net zero emissions	Yes	2050	No		Unclear	Scope 1 & 2
Salesforce.com	Net zero emissions	Yes	already achieved, new target 2030	Yes	Yes	Yes	Scope 1, 2 & 3
Rolls-Royce	Net zero emissions	Yes	2050	Yes	Yes	Unclear	Scope 1 & 2
Thor Industries	Net zero emissions	Yes	2050	Yes	Yes	Unclear	Scope 1 & 2

Appendix D - Overview data collection

Phase 1 – in consultation with NewClimate		Phase 2 – random sample			
Company	**Net zero target**	**Company**	**Net zero target**	**Company**	**Net zero target**
Boston Consulting Group	Yes	OP Financial	Yes	Enel	Yes
Velux	Yes	SHANGHAI QIRUI ELECTRIC LIGHTING	No	Godrej Consumer Products Limited	Yes
Apple	Yes	SingTel	Yes	Mad Fish Digital	No
Amazon	Yes	Hollingsworth, Inc.	No	Rosario Bio Energy	No
Vodafone	Yes	TUI	No	Yarra Valley Water	Yes
Sky	Yes	BP	Yes	Ocean Observations	No
Virgin	No	Pachama	No	Southampton Airport	Yes
IAG	Yes	Almond Impact Ltd	No	Pidigi S.P.A.	No
Total	Yes	Comercial Epullen Limitada	No	Mobilidee	No
Adidas	Yes	Jet2.com	No	Teadora	No
H&M	Yes	Tendam Retail S.A.	Yes	Ecorobotix Sa	No
HEMA	No	OOHM BV	No	MetLife	Yes
Easyjet	Yes	Emprediem Argentina	No	NRG Energy	Yes
Siemens	Yes	Aber Food Surplus	No	STMicroelectronics	Yes
Alecta	Yes	Anko	No	Tdc A/S	Yes
Maersk	Yes	Strong Tower Consulting	No	Green Commuter	No
ArcelorMittal	Yes	NINGBO FIVE PEAK MACHINERY CO., LTD.	No	Ferrocarrils de la Generalitat de Catalunya (FGC)	No
HeidelbergCement	Yes	GSL - Global Star Logistics	No	Allplants	No
PetroChina co	Near zero	Farfetch	No	Wonderland	No
BP	Yes	Tennant Company	No	Chambers Federation	No
Philips	Yes	Eq Investors	Yes	Centrica	Yes
Microsoft	Yes	Church & Dwight Co	Yes	SÃ¸Ren Jensen Consulting Engineers	No
Novo Nordics	Yes	Pur Projet	No	Vera Solutions	Yes
SAP	Yes	Advanced Micro Devices	No	Salesforce.com, Inc.	Yes
RWE	Yes	New Balance Athletics	No	Third Sun Solar	No
Volkswagen	Yes	Husqvarna AB	Yes	Montagne Alternative	No
DHL	Yes	Danone Waters Germany	No	Kokusai Kogyo Co., Ltd.	No
Shell	Yes	Bancolombia	No	Rolls-Royce	Yes
		Thor Industries	Yes	Ecoadvisors Inc.	No

Appendix E - Sector overview

Transport
IAG
EasyJet
Maersk
DHL

Heavy industry
ArcelorMittal
HeidelbergCement

Fossil fuels
Total
PetroChina co
BP
Shell

Finance/services
OP financial
MetLife
Boston Consulting Group

Energy
RWE
Enel
NRG Energy
Centrica

Telecom/internet
Vodafone
Sky
Microsoft
SAP
Singtel
TDC A/S
Salesfore.com

Apparel
Adidas
H&M
Tendam

Manufacturing
Velux
Siemens
Philips
Volkswagen
Rolls-Royce
Husqvarna AB
Godrej CP
STMicroelectronics
Church & Dwight
Thor Industries

Undefined
Amazon
Apple
Novo Nordisk
Yarra Valley Waters
Southampton Airport