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Up to half of companies would be behind on their climate targets under stricter scope 2 accounting rules

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Abstract

Companies have been accused of overstating their scope 2 emission reductions through purchases of ineffective renewable energy certificates (RECs). Therefore, several actors have proposed stricter accounting rules targeting additionality and deliverability. In this paper we explore how such restrictions would quantitatively affect the scope 2 emissions and target progress reported by companies. We consider three accounting restrictions: geographical proximity, facility age, and power purchase agreement. The study involves adjusting the market-based scope 2 emissions reported by 206 companies based on the portion of their purchased RECs that would become invalid under the proposed accounting restrictions. We find that the sample companies have more than doubled their purchases of RECs between their base year (typically 2019) and 2022, including an increase in RECs that would be invalid under the proposed accounting restrictions. The introduction of all three accounting restrictions would entail that the combined scope 2 emission reduction reported by the sample companies falls from 21% to 17%. Similarly, the share of sample companies that were behind on their climate target in 2022 would increase from 28% to 50% under all three accounting restrictions. However, a small subset of the company sample has over time replaced potentially invalid RECs with valid RECs, and the accounting restrictions would lead to improved target performance for these companies. Our findings can inform the revision of the greenhouse gas protocol and emerging accounting standards around renewable fuels.

1. Introduction

Since the 2015 Paris Agreement there has been an increasing focus on corporate greenhouse gas (GHG) reduction targets and their role in limiting global warming to well-below 2 degrees (Bjørn *et al* 2022c). These targets are typically expressed as a percentage reduction (such as 50%) in specified emission categories (e.g. scope 1, 2 or 3) between a base year (such as 2019) and a target year (such as 2030) (Bjørn *et al* 2023). Initiatives like the Science Based Targets Initiative (SBTi 2024b), Net-Zero Tracker (NZT 2024) and a dedicated United Nation Expert Group (UN 2022) are guiding companies on how to set GHG targets that are 'Paris-aligned'. While considerable expectations surround corporate climate action, there are concerns that current GHG accounting rules allow companies to report the fulfillment of emissions reduction targets without actually reducing emissions (Giesekam *et al* 2021, Bjørn *et al* 2022b, Axelsson *et al* 2024, NewClimate Institute 2024a). A particularly contested accounting practice is the use of environmental attribute certificates, which are contractual arrangements that allow companies to use low emissions factors when calculating their GHG inventories (Brander and Bjørn 2023). This paper

explores how proposed stricter rules for such certificates would impact the number of companies that appear to be on track with their reduction targets.

Currently, the GHG Protocol (GHG Protocol 2015) allows companies to use a type of attribute certificate called renewable energy certificates (RECs) when reporting emissions from purchased electricity[5] (scope 2). Under this approach power consumption that is 'matched' by certificates purchased from renewable energy facilities will be reported as having zero emissions in corporate GHG inventories. This market-based accounting approach has been criticized for not ensuring compliance with *additionality* and *deliverability* criteria (Brander and Bjørn 2023, Langer *et al* 2024). In terms of *additionality*, the purchasing of RECs does not necessarily lead to more generation of renewable energy, in which case emission reductions claimed through RECs would be overstated (Brander *et al* 2018, Bjørn *et al* 2022a, 2022b, Ruiz Manuel and Blok 2023, Paris *et al* 2024). Regarding *deliverability*, companies can currently purchase RECs linked to electricity generation that cannot physically be delivered to them, due to a geographical or a temporal mismatch[6] (Robinson and Sullivan 2022, Ricks *et al* 2023, Xu *et al* 2024), hence violating the principle of physical connectivity that is a core feature of inventory-based emissions accounting (Brander and Bjørn 2023).

In response to these criticisms, different proposals have been made for tightening market-based scope 2 emission accounting rules (Brander and Bjørn 2023, Brander *et al* 2024, Langer *et al* 2024, Sievert *et al* 2024). Proposals targeting *additionality* include the suggestion that companies must source RECs through power purchase agreements (PPAs)[7] (Bjørn *et al* 2022b, NewClimate Institute 2024b) and that the facilities selling the RECs should have recently started to operate (European Commission 2023b, Paris *et al* 2024). Proposals targeting *deliverability* recommend that companies must purchase RECs solely from renewable electricity generators in close geographical proximity (Robinson and Sullivan 2022) and that companies must match their power consumption in every hour by RECs linked to power production in the same hour (Chalendar and Benson 2019, Google 2020, Scholta and Blaschke 2024). These and other proposals[8] are currently discussed in the context of the upcoming revision of the GHG Protocol guidance (GHG Protocol 2023a, 2023b) and regulations related to renewable fuels (DOTT 2023, European Commission 2023b).

In this study, we seek to inform these discussions by quantifying how proposed tightening of emission accounting rules would affect companies' scope 2 emissions in an 'all else equal' scenario and the implications for the companies' performance against their emission reduction targets. Our study involves adjusting the market-based scope 2 emissions reported by a sample of 206 companies in the company-specific base years and the year 2022 to model scenarios in which a portion of their purchased RECs would become invalid under the proposed stricter accounting rules. Through our analysis, we identify the types of companies whose target performance would either worsen or improve under the newly proposed accounting rules. Due to data limitations, we focus on the accounting proposals related to PPAs, facility age and geographical proximity, while we briefly address the accounting proposal related to hourly matching in the discussion.

2. Methods

2.1. Determining the company sample

In determining the company sample, we aimed to both include a representative number of companies and use high quality and standardized company data. To ensure standardized data from many companies, our starting point was the CDP dataset, involving 10 832 companies' public responses to the Investor and Supply Chain Climate Change Questionnaires for the year 2023 (covering the reporting year 2022), as well as to earlier questionnaires. We then applied eight filters to focus on companies engaging in REC purchasing (filter 4), that disclose sufficient information (filter 1–3 and 5–7), and which appear internally consistent (filter 8) (table 1).

The resulting company sample is dominated by large companies (high revenue class) (73%)

[5] Scope 2 also covers emissions from purchased heat, steam and cooling. These are typically small compared to emission from purchased electricity.

[6] For example, a company located in mainland Europe can currently purchase RECs originating from Icelandic hydropower plants to report emission reductions, even though Iceland has no grid connection to mainland Europe (Hufen 2017). Likewise, a company with continuous electricity consumption can currently 'match' its entire consumption with RECs issued from solar panels, even though other electricity generation technologies are required to meet its night-time demand, in absence of battery storage (de Chalendar and Benson 2019).

[7] A long-term contract by which a company buys (i) certificates together with electricitydirectly from a renewable energy generator, taking physical delivery of the electricity (physical PPA) or, (ii) the certificates together with a price hedging contract for the electricity (virtual PPA) (Langer *et al* 2024).

[8] Another notable accounting proposal, sometimes referred to as impact reporting, encourages companies to focus their RECs purchases on regions and times with the highest potential to displace carbon emissions from fossil energy generation (He *et al* 2021, GHG Protocol 2023b, 2024). This proposal falls under intervention (or consequential) accounting (Brander and Bjørn 2023), while our study focuses on accounting proposals under inventory-based (or attributional) accounting. Note also that some actors are against tightening existing GHG Protocol accounting rules, fearing that this would restrict the number of companies buying RECs and ultimately lead to less aggregate renewable energy deployment (O'Shaughnessy 2024).

Table 1. The eight filters developed for determining the company sample and the number of sample companies remaining after the sequential application of each filter. See Supplementary Material (SM) 1 for additional details and justifications for each filter.

Filter	Number of companies remaining
0. Full CDP sample	10 832
1. Disclosed an emission reduction target for market-based scope 2 emissions	1,876
2. Disclosed scope 2 emissions	1,497
3. Disclosed power consumption	1,062
4. Purchased RECs in 2022	931
5. Disclosed REC type (PPA or other) for each purchase	930
6. Disclosed geographical origin for each REC purchase	852
7. Disclosed facility age for each REC purchase	230
8. Passed data consistency test	206

headquartered in Asia (38%), Europe (35%) and North America (22%), with the three most common industries being Manufacturing (33%), Services (18%) and Materials (12%). Three quarters of the sample companies were members of SBTi (58%), RE100 (2%) or both (15%) (Egli *et al* 2023, Ruiz Manuel and Blok 2023). Compared to the characteristics of all 10 832 companies publicly disclosing to CDP in 2023, the company sample is fairly representative for headquarter locations and industries, while it overrepresents large companies and companies that are members of SBTi and RE100 (see SM 2 for details).

2.2. Quantifying the portion of valid RECs under proposed accounting restrictions

The three proposed accounting restrictions must be concretized to enable a calculation of the share of RECs that would be considered valid under each. For the PPA restriction, we build on earlier studies (Bjørn *et al* 2022b, Ruiz Manuel and Blok 2023) and consider RECs linked to all types of PPA as valid[9]. To assess the robustness of our study's findings, we develop an additional stricter scenario requiring PPAs to be physical[10].

For the geographical proximity restriction, we consider RECs to be valid if they originate from the same country as the energy consumption, while noting that others have called for stronger restrictions (Robinson and Sullivan 2022).

We set the facility age restriction to 36 months following the age limit included in the European Commission's delegated renewable fuels regulation (European Commission 2023b) and similar regulations in the US (DOTT 2023). In line with that regulation, we further consider RECs linked to PPAs valid if the difference between the commissioning year of the energy facility and the year that the PPA was signed (rather than the year the RECs are purchased) is no more than three years.

Note that companies did not systematically disclose the information needed to evaluate REC validity for the geographical proximity and facility age restrictions in the reporting years 2015–2020. For these years, we therefore assumed that the RECs purchased by each sample company had the same proportions of validity concerning these two restrictions as was observed for the reporting year 2022 for the company sample in aggregate (more details on the handling of missing data in SM 3). In addition, we developed a sensitivity scenario assuming that all non-PPA related RECs purchased in 2015–2020 were invalid with respect to the two restrictions.

We then calculated the valid portion of each sample company's purchased RECs in 2022 and in the company-specific base year (typically 2019) according to each of the three accounting restrictions, as well as all four combinations of multiple accounting principles (Geographical proximity + PPA, PPA + Facility age, Geographical proximity + Facility age, Geographical proximity + PPA + Facility age).

2.3. Adjusting reported market-based emissions

Our approach to adjusting the sample companies' reported scope 2 emissions in 2022 and in the base years was inspired by Bjørn *et al* (2022b) and involved the estimation of a residual emission factor, followed by multiplication with the valid portion of RECs:

$$E_{\text{reported\_MB}} = C_{\text{REC}} \cdot \text{EF}_{\text{REC}} + (C - C_{\text{REC}}) \cdot \text{EF}_{\text{res}} \approx (C - C_{\text{REC}}) \cdot \text{EF}_{\text{res}} \quad (1)$$

$$\text{EF}_{\text{res}} = \frac{E_{\text{reported\_MB}}}{C - C_{\text{REC}}} \quad (2)$$

$$E_{\text{adjusted\_MB}} = (C - C_{\text{REC\_valid}}) \cdot \text{EF}_{\text{res}}. \quad (3)$$

Equation (1) presents the standard equation to calculating market-based scope 2 emissions under the GHG Protocol (GHG Protocol 2015, Bjørn

[9] This includes physical PPAs, virtual PPAs, grid-connected PPAs, direct-line PPAs, on-site PPAs and PPAs without RECs as a tracking instrument for the generator's emission factor.

[10] This includes physical PPAs, grid-connected PPAs, direct-line PPAs and on-site PPAs.

et al 2022b), with $E_{reported\_MB}$ denoting the company's reported market-based scope 2 emissions (tCO_2e/year), C denoting its consumed electricity[11] (MWh/year), C_{REC} denoting the quantity of RECs (MWh/year), EF_{REC} denoting the emission factor associated with the RECs (tCO_2e/MWh) and EF_{res} denoting the residual emission factor (tCO_2e/MWh), which represents the location's average emission factor adjusted upwards for the portion of generated renewable energy that has been claimed through RECs. Following Bjørn *et al* (2022b), we further assume that EF_{REC} (which companies rarely disclose) is zero, thus simplifying equation (1). Equation (2) then isolates EF_{res} from equation (1). Finally, equation (3) calculates $E_{adjusted\_MB}$, the adjusted market-based scope 2 emissions, following estimations of the valid volume of RECs, C_{REC_valid}, in section 2.2.

For the 14 sample companies matching 100% of their electricity purchases with RECs, the approach above is not valid, since $C-C_{REC}$ would be zero, leading to no solution to equation (2). We instead used an alternative approach to adjusting these companies' market-based scope 2 emissions, see SM 4.

Note that the GHG Protocol (GHG Protocol 2015) requires companies to use equation (1) on individual sites and for individual forms of purchased energy (electricity, heat, steam and cooling) followed by aggregation to calculate company-wide market-based scope 2 emissions. However, due to a broad lack of disclosure on facility-level scope 2 emissions and power consumption, our main results reflect a simplified situation where each sample company is treated as operating in a single region with a single residual emission factor. We estimate the uncertainty resulting from this simplification by additionally using equations (1)–(3) on individual company sites, followed by aggregation, for the 24 case companies that disclosed sufficient and consistent facility-level data.

2.4. Analyzing GHG target performance under reported and adjusted emissions

First, we assessed the target performance of individual companies according to their reported scope 2 emissions, reflecting current market-based emission accounting rules (GHG Protocol 2015). Following existing target performance literature (Wang 2017, Giesekam *et al* 2021, Bolay *et al* 2022, Science Based Targets Initiative 2023), we used an assumed linear emission reduction pathway from base years (most frequently 2019) to target year (most frequently 2030) to calculate targeted scope 2 emissions in 2022 and compared this to the reported scope 2 emissions for 2022 to decide if a company was ahead or behind. For companies targeting a single percentage reduction for a combination of emission scopes, such as scope 1 and 2 combined, we assumed that the percentage reduction also applies to scope 2 alone. Next, we assessed target performance considering the adjusted emissions for 2022 and the base years as well as a corresponding adjustment of target year emissions. Figure 1(a) illustrates a case where a company's reported emissions for 2022 appear to be on track, while its adjusted emissions are off track, and figure 1(b) illustrates the opposite case. Note that, for the sake of simplicity, our approach to studying changes in target performance assumes that companies will not make any changes to their targets (e.g. choice of base year, target year or percentage targeted reduction) under the new accounting rules (see section 4.2 for a discussion).

3. Results

In this section, we report results for the company sample as a whole. The key results are largely similar for individual company groups, differentiated according to headquarter location, industry, size (by revenue class) and membership of RE100 or SBTi, and the variations in results do not follow a clear pattern (see SM 5). Results for the stricter variant of the PPA restriction involve more invalid RECs purchases, especially for 2022, higher adjusted emissions and worse target performance than the main results shown below (see SM 6).

3.1. Changes in valid RECs under proposed accounting restrictions

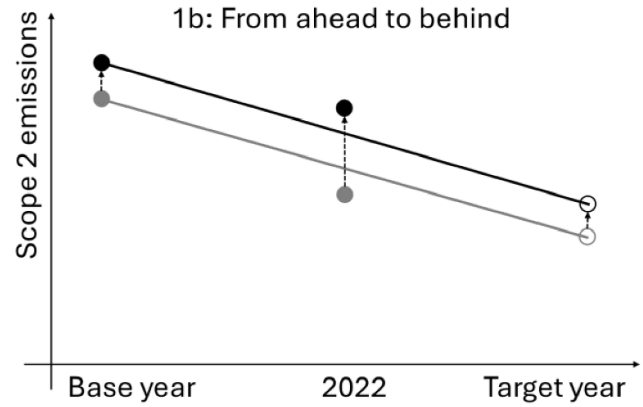
Here, we show that while most purchased RECs appear to comply with the proximity restriction, additional restrictions would result in a sharp drop in the share of RECs that are considered valid, and that this impacts companies mainly in the year 2022 due to an increased reliance on RECs as compared to the base years.

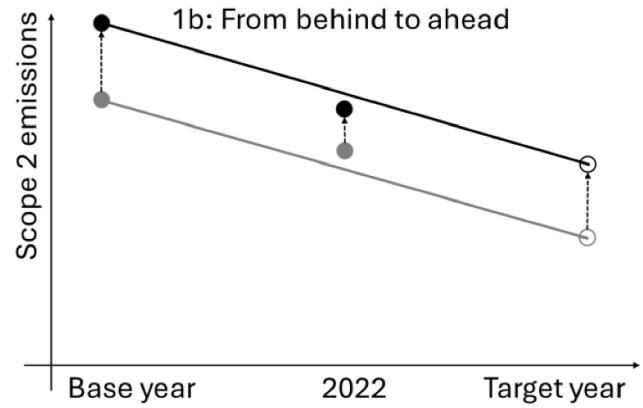
The 206 companies increased their total power purchases by 6.1% from the base years to 2022 (360TWh to 382TWh), while their RECs purchases saw a much greater increase (141%) resulting in 21% of the power consumption being matched by RECs in 2022[12] (figure 2(a)). In both years, the purchased RECs largely (>99%) fell into four categories of accounting restrictions[13] (figure 2(b)): not

[11] In the remainder of this paper, we use 'electricity' or 'power' as a shorthand for 'power, heat, steam and cooling' unless otherwise noted.

[12] For reference, the RECs purchased by the sample companies in 2022 (82TWh) correspond to roughly a third of all RECs purchased by corporations in the US in that year: the entire voluntary US RECs market was reportedly 273TWh in 2022 (O'Shaughnessy *et al* 2023, NREL 2024) and this number reduces to 250TWh when removing residential purchases, assuming the residential market shares estimated by O'Shaughnessy *et al* (2021).

[13] On the other hand, it was very rare for the purchased RECs to comply with the age restriction alone, the PPA restriction alone, the PPA and age restriction combined, or the PPA and proximity restriction combined.





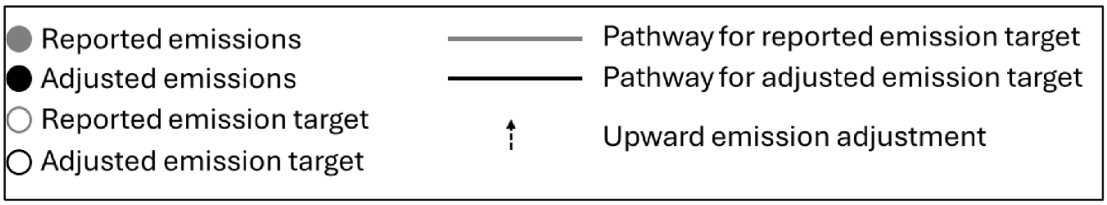


Figure 1. Illustration of target performance assessment for reported and adjusted emissions with a case where reported emissions are ahead of the target, while adjusted emissions are behind (1a) and another case with the opposite scenario (1b). Note that the reported and adjusted target year emissions in the two cases reflect the same fixed percentage reduction in base year emissions.

complying with any accounting restrictions (1%–2%); complying with the proximity restriction alone (34%–50%); complying with the proximity restriction and the age restriction (21%–35%) and complying with all three restrictions, i.e. proximity, age and PPA (13%–44%). We therefore focus on these four combinations of accounting restrictions in the remainder of the paper. Overall, the results indicate a large increase in the reliance of RECs over time (figure 2(a)), while the share of purchased RECs that comply with all three restrictions, has also increased (figure 2(b)).

Much heterogeneity is hidden underneath these aggregated results. Around half of the sample companies did not buy any RECs in their base year, while six companies matched more than 90% of their purchased power with RECs (figure 3(a), first box[14]). However, only one of those six companies exclusively purchased RECs complying with all three restrictions (figure 3(a), last box). In 2022, a typical company matched around a third of its power consumption by RECs (figure 3(b), first box: median of 30%). This would also be true under the proximity restriction (figure 3(b), second box: median of 29%). However, adding the age restriction would result in a sharp decrease in power consumption matched by valid RECs (figure 3(b), third box: median of 5%), and most companies (58%) did not purchase any valid RECs under all three restrictions (figure 3(b),

[14] Note that two of the six datapoints above 90% overlap in the figure 3(a) plot.

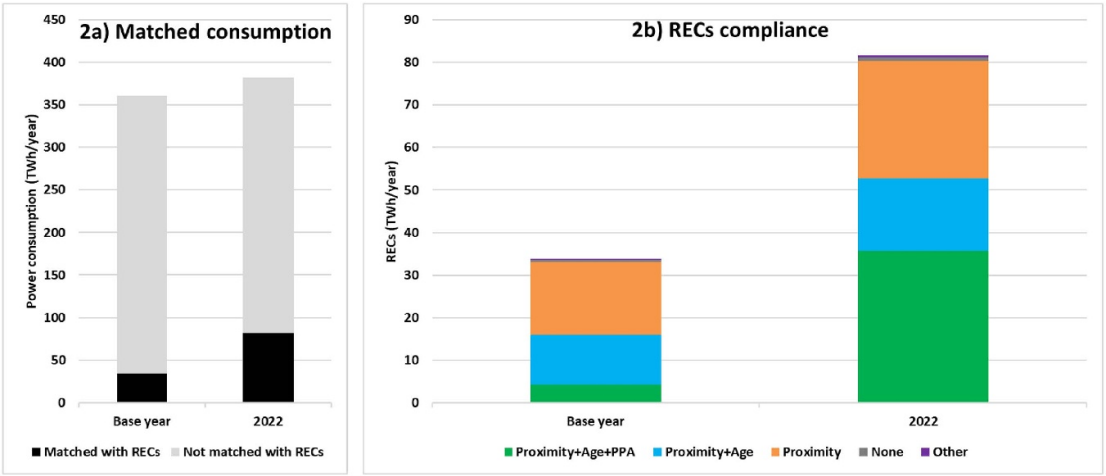


Figure 2. Total power consumption and RECs matching by the 206 sample companies (2a) with indications of the accounting restrictions that the purchased RECs comply with (2b). 'Other' covers the remaining four categories of restrictions, see footnote [13]. The base year is specific for each company. See supplementary data for underlying data.

last box). Hence, while the sample companies generally increased their reliance on RECs between the base years and 2022, imposing the proximity and age restrictions would make a big portion of the 2022 purchases invalid and even more so if also imposing the PPA restriction.

3.2. Adjustment of scope 2 emissions under proposed accounting restrictions

Here, we show how the proposed accounting restrictions would lead to higher upward adjustments of scope 2 emissions in 2022 than in the base years, thereby shrinking the apparent decarbonization achieved by the companies over the period.

The sample companies' disclosures show a total reduction in market-based scope 2 emissions of 21% from the base years to 2022 (a decrease of 29 Mtonne CO_2e/year from 141 to 112 Mtonne CO_2e/year) (figure 4, first column). Imposing the proximity restriction would cause a minimal change in that result, as nearly all RECs purchased in the base years and in 2022 complied with this restriction[15] (figure 2). However, imposing all three restrictions would shrink the apparent emission reduction to 17% (and to 18% for the proximity and age restrictions combined). This is because the increased reliance over time on RECs that do not comply with all three restrictions (figure 2) results in a greater upward adjustment in the companies' scope 2 emission in 2022 (16 Mtonne CO_2e/year) than in the base years (13 Mtonne CO_2e/year). Hence, the combined extent of decarbonization achieved by the sample companies appears higher under current accounting rules than under proposed restrictions.

At the company level, a tendency of greater upward adjustments of 2022 emissions than of base year emissions under the strictest accounting rules is also observed (figure 5). While three quarters of companies see no more than a 10% upward adjustment of base year scope 2 emissions under all three accounting restrictions (figure 5(a), green bars), most companies (55%) get their 2022 emissions adjusted upwards more than 10%, and a quarter of companies would see their 2022 emissions more than double (figure 5(b), green bars). This discrepancy in emission adjustments between the base years and 2022 is similar if only imposing the proximity and age restrictions (figure 5, blue bars). However, only requiring the proximity restriction leads to minor emission adjustments for most companies in both the base years and in 2022 (figure 5, orange bars), as few RECs did not comply with that restriction in either year (figure 3).

3.3. Changes to GHG target performance under proposed accounting restrictions

Here, we show that the proposed accounting restrictions would generally impact the target progress of companies negatively, while a minority of companies would see an improved target performance.

More than two thirds (72%) of the sample companies were reportedly ahead on their scope 2 reduction targets in 2022 (figure 6, first column). However, adjusting the emissions upward in line with the different accounting restrictions reduces the share of companies that are ahead on their target to as little as 50% (figure 6, last column). The worsening overall

[15] The reason that the proximity restriction would lead to a slightly higher emission reduction (30.1 Mtonne CO_2e/year) than in the baseline (29.1 Mtonne CO_2e/year) is that we estimated a slightly higher compliance with that restriction in 2022 than in the base years, leading to a somewhat higher upward adjustment of base year emissions than of 2022 emissions.

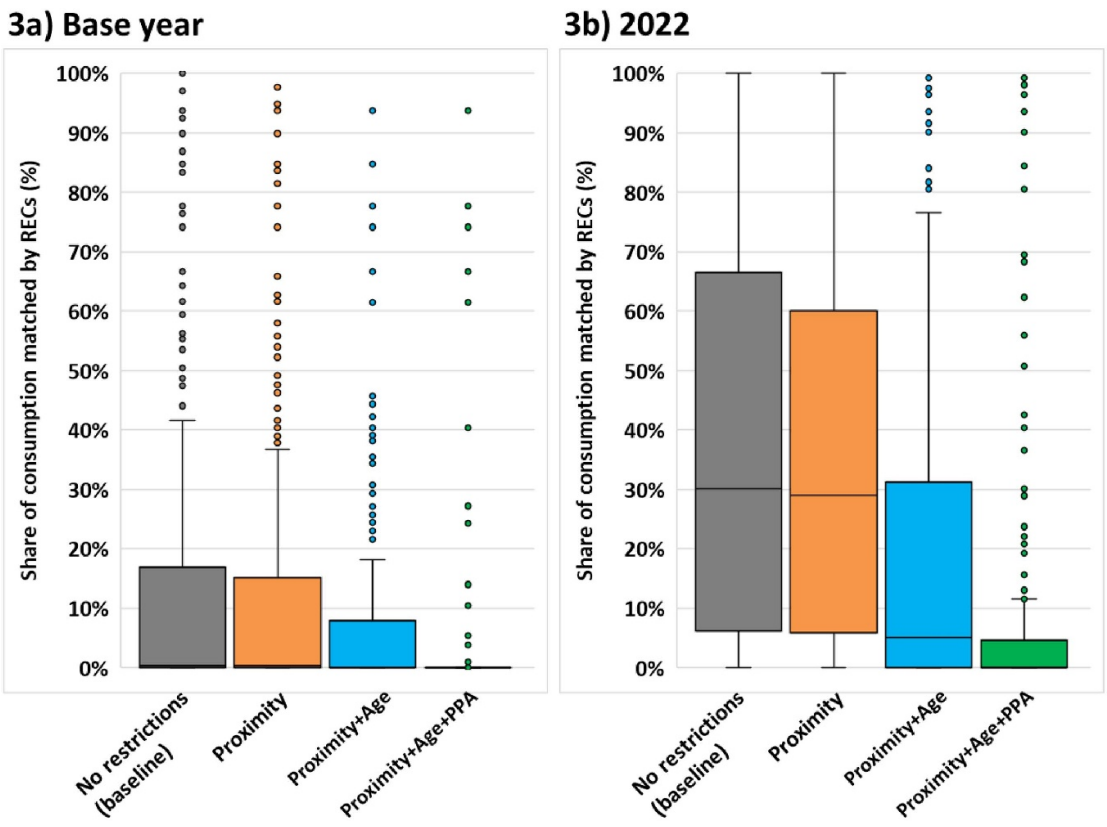


Figure 3. Share of power consumption matched by RECs for the 206 sample companies in the company-specific base years (3a) and 2022 (3b) under different accounting restrictions. Boxes indicate 25–75th percentile ranges. Horizontal lines within boxes indicate medians. Whiskers (i.e. non-outlier ranges) indicate datapoints within 1.5 times the 25–75th percentile ranges. Circles indicate outliers. See supplementary data for underlying data.

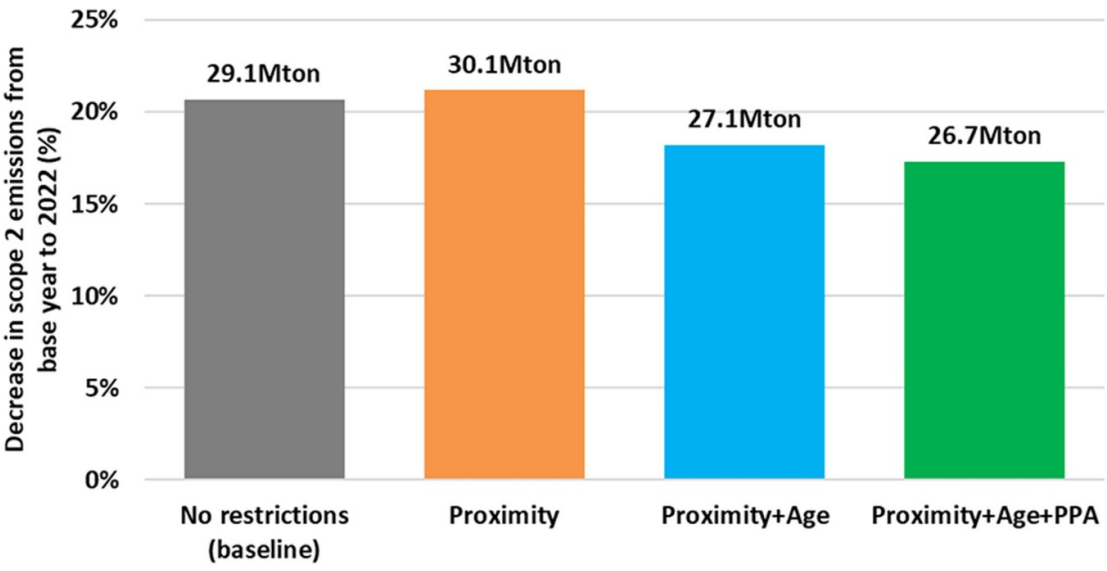


Figure 4. Percentage decrease in total market-based scope 2 emissions from the company-specific base years to 2022 under different accounting restrictions. The values above the columns indicate the corresponding absolute emission decreases. See supplementary data for underlying data.

target performance is due to companies that over time have increased their reliance on RECs that would be invalid according to the proposed accounting restrictions (as illustrated in figure 1(a)). However, note that 3% of the sample companies switched from being behind to being ahead on their GHG targets after having their emissions adjusted for all three accounting restrictions (supplementary data to figure 6). This small minority of sample companies have transitioned from largely purchasing invalid RECs in

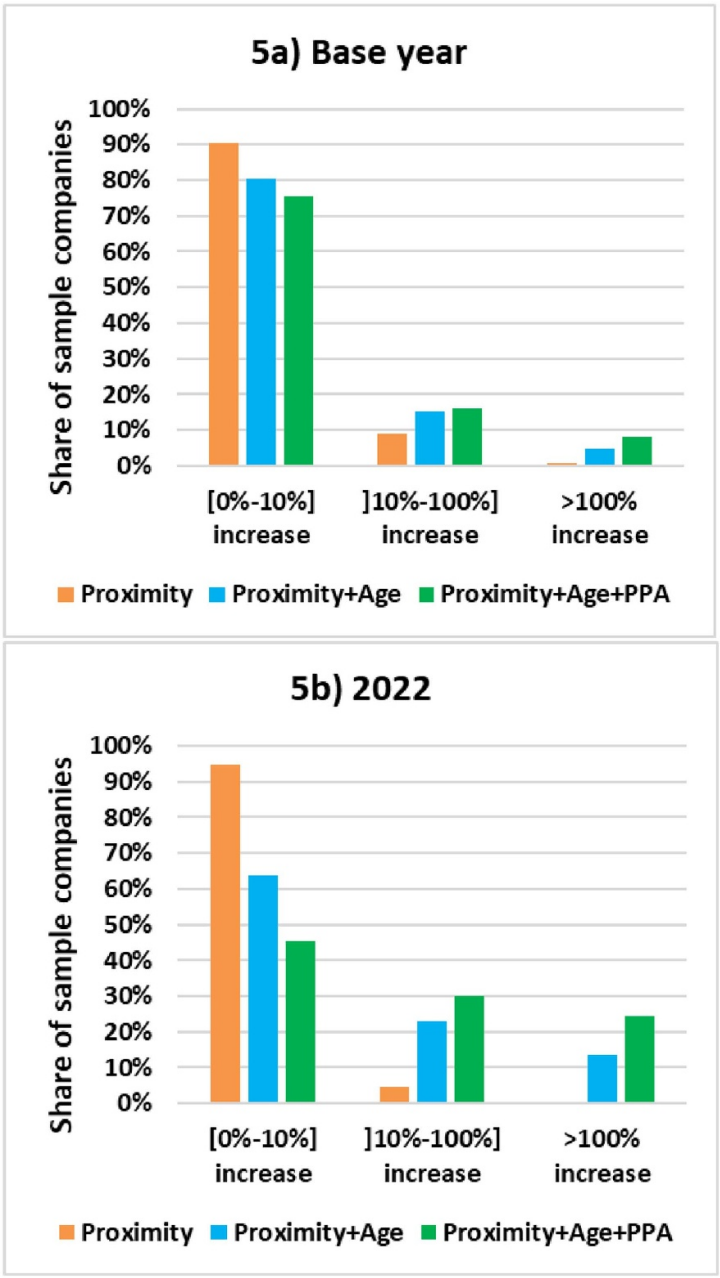


Figure 5. Company distribution for the upward adjustments in reported market-based scope 2 emissions under different accounting restrictions in the company-specific base years (5a) and 2022 (5b). The chart covers 192 case companies and excludes the 14 case companies that matched 100% of their electricity purchases with RECs (see section 2.4), as it is not possible to calculate a percentage increase from a base value of zero emissions. See supplementary data for underlying data.

the base years to largely purchasing valid RECs in 2022 (as illustrated in figure 1(b)). The introduction of the proximity restriction alone would not affect the reported target performance (compare the first two columns of figure 6), while combining the proximity and age restrictions has a moderate impact on target performance (from 72% to 62% ahead, see figure 6). Hence, even though the upward emissions adjustments under the proximity and age restrictions appear close to the case of all three restrictions (compare blue and green bars in figures 4 and 5), the addition of the PPA restriction leads to a substantial additional worsening of target performance (compare the last two columns of figure 6).

4. Discussion

4.1. Novelty and comparison to existing literature

Our study was motivated by concerns that current GHG accounting rules allow companies to report the fulfillment of emissions reduction targets without actually reducing emissions (NewClimate Institute 2024a). We find a surge in company purchases of RECs over time, meaning that RECs are playing an

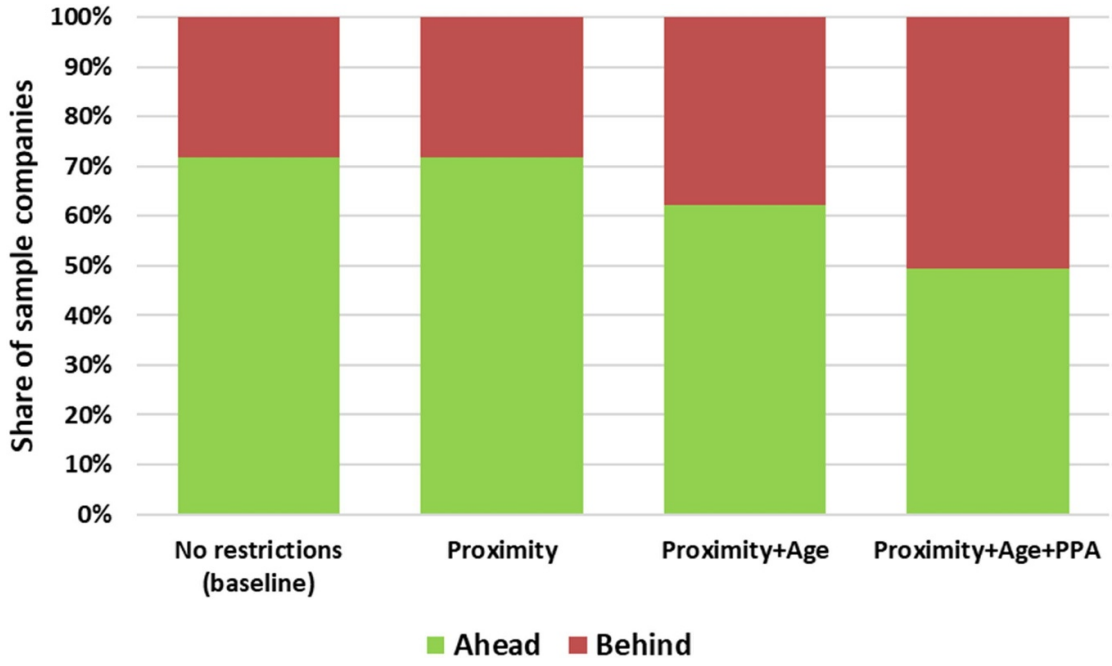


Figure 6. Share of the 206 sample companies that are either ahead or behind on their emission reduction target according to reported market-based scope 2 emissions (first column) and under different accounting restrictions (remaining columns). See supplementary data for underlying data.

increasing role in reported scope 2 emission figures. If stricter emissions accounting rules are put in place, substantial shares of these purchased RECs would become invalid, shrinking the apparent scope 2 emission reductions achieved by the companies. As a result, as many as 50% of the companies, up from 28%, would be behind on their climate targets under these stricter and potentially more accurate accounting rules.

Our study is the first quantitative assessment of the implication of potential new scope 2 accounting rules on companies' reported emissions and target progress. Our findings that companies buy increasing volumes of RECs over time and that the share of RECs linked to PPAs is also increasing over time are in agreement with existing literature (Bjørn *et al* 2022b, Egli *et al* 2023, O'Shaughnessy *et al* 2023, Ruiz Manuel and Blok 2023, Fedson *et al* 2024, NREL 2024). However, we find higher rates of compliance with the facility age restriction (98% in 2022, see figure 2) than the only other study known to us that quantifies compliance with this restriction (83%[16]) (Fedson *et al* 2024). The narrower scope of that study (RECs purchases in Europe by RE100 member companies) may potentially explain this discrepancy.

4.2. Limitations and future work

Our study is based on companies' voluntarily self-reported climate data. While our company sample selection was designed to avoid clearly inconsistent data (section 2.1), it is hard to fully gauge the trustworthiness of the sample data. However, one indication of inaccurate data is the apparent near-universal compliance with the geographical proximity restriction (figures 2 and 3), which conflicts with reports from RECs program operators showing that many countries, such as Norway and France, export substantial volumes of issued RECs (Mulder and Zomer 2016, Holzapfel *et al* 2024, Paris *et al* 2024) that are then used in the emission claims of companies (and other electricity consumers) in other countries (Hufen 2017). It may be that some sample companies wrongly reported that purchased RECs came from the same country as the location of electricity consumption because they believed that RECs sold by a local vendor also originate locally. More research is needed to test this hypothesis. More broadly, emerging government mandates on corporate climate data disclosure (European Commission 2023a) should seek to ensure high quality of the disclosed data (Hale *et al* 2024).

Our study is also limited by the extent and granularity of the corporate data. The CDP data generally refers to annual periods and this inhibits an understanding of how hourly scope 2 emission accounting, motivated by deliverability concerns (de Chalendar and Benson 2019, Google 2020, Scholta and Blaschke 2024), would affect the reported emissions. Existing studies indicate that hourly accounting may benefit certain companies, e.g. those already consuming most electricity during hours with a clean grid and high availability of RECs, while disadvantaging others

[16] Fedson *et al* (2024) report that around 17% of total REC purchasing in Europe by RE100 member companies in 2022 is cross-border.

(Miller *et al* 2022, Scholta and Blaschke 2024). CDP and other disclosure platforms should enable companies to report scope 2 emissions based on hourly accounting in a standardized way. Likewise, disclosure platforms should encourage location information at higher resolution than the country level (Robinson and Sullivan 2022) and data about novel REC types, such as RECs with price floors, which have been proposed as an indication of additionality (Ever.green 2024) or RECs with information on the specific time of generation (e.g. date and hour). Such higher granularity in disclosures would allow for assessments of the potential positive effects of deliverability requirements on the additionality of RECs. Existing studies (Langer *et al* 2024, Paris *et al* 2024, Xu *et al* 2024) indicate that new deliverability requirements may change the relationship between RECs supply and demand, thereby increasing REC prices in locations and times with high demand and low supply. This could potentially lead to REC types that were previously considered to be non-additional to cause the production of additional renewable energy. Our study assumes that companies used residual emission factors to calculate market-based scope 2 emissions from the portion of their electricity consumption that is un-matched with RECs (equation (1)), in accordance with the emission factor hierarchy of the GHG Protocol (GHG Protocol 2015). However, companies may in practice resort to using average emission factors in cases where high-quality residual emission factors are not readily available to them, which could lead to substantial underestimations of their market-based scope 2 emissions (Paris *et al* 2024). It is therefore crucial that companies report all emission factors behind their scope 2 disclosures along with appropriate metadata.

While the gradual increase in quantity and quality of corporate climate data in the CDP dataset is commendable, it also means that our results for 2022 are more certain than our results for the company-specific base years. However, our target progress assessment appears robust: When leaving out the 79 companies that had recalculated base year emissions due to structural changes or discovery of errors, the key results for the remaining sample were nearly identical to the key results for the full sample (see SM 7). Likewise, if assuming that all non-PPA related RECs purchased in the base years did not comply with the proximity or age restrictions (elaborated in section 2.2), the share of companies that would be ahead on their target under all three accounting restrictions combined is unchanged (SM 8)[17]. Finally, the site-level approach for 24 case companies (elaborated in section 2.3) generally resulted in similar emission adjustments as the main approach, leading to the same outcome in the target progress assessment for all but one company (SM 9).

Our study involves an 'all else equal' approach in which stricter accounting rules do not make companies change their behavior. In reality, companies are likely to avoid spending money on 'invalid' RECs. Stricter accounting rules might also lead to some companies decreasing the ambition of their climate targets. For example, according to SBTi's criterion C27, 'Significant adjustments to the base year inventory, data sources or calculation methodologies…' should trigger the need for a company to recalculate its reduction target (SBTi 2023). It may therefore be that potential changes to the GHG Protocol's scope 2 accounting rules would give companies with substantial purchases of RECs in the base year the opportunity to set new SBTs, or this may even become a requirement. Without the option to report scope 2 emissions reductions through low-cost RECs, companies may also increase efforts to save energy (Ascui *et al* 2021). Future research should explore such potential behavioral impacts of emission accounting rules.

4.3. Recommendations to individual actors

For the GHG Protocol, our findings show that there will be some companies that are adversely affected by proposed restrictions of scope 2 accounting rules related to deliverability and additionality. This entails that the GHG Protocol will have to manage any transition very carefully. We recommend clearly communicating the necessity and greater medium to long-term benefits of high integrity accounting, such as avoidance of reputational risk, over any short-term impacts to companies that will need to adjust their climate plans. On the other hand, we also show that a substantial share of companies are already seeking out RECs associated with additionality and deliverability (figure 2(b)). These companies would therefore not be adversely affected by the proposed restrictions (figure 6) and may even support them.

For companies, our findings show that what may currently be the easiest path to reporting large scope 2 emission reductions (buying the lowest cost RECs) could backfire if new emission accounting rules are put in place. Companies should anticipate this scenario and futureproof their scope 2 emission strategy by pursuing options involving deliverability and additionality. The handful of sample companies that would improve their target performance under stricter accounting rules (figure 1(b) and supplementary data to figure 6) may serve as an inspiration. Likewise, if environmental attribute certificates end up playing a larger role in scope 1 and scope 3 accounting rules (GHG Protocol 2024, SBTi 2024a), companies could avoid reputational risk and hedge against potential future accounting restrictions by

[17] However, in this scenario the introduction of the geographical proximity restriction alone would actually lead to improved overall target performance (SM 8). This is because the scenario involves a switch in RECs purchases that do not comply with the proximity restriction in the base years to RECs purchases that nearly always comply with the proximity restriction in 2022.

sourcing attributes associated with deliverability and additionality from the get-go.

For company stakeholders, such as impact investors aiming to identify climate responsible companies, our study adds to calls for going deeper than simply screening target ambition and reported target progress (Bolay *et al* 2022, 2024, NewClimate Institute 2024a, 2024b). Stakeholders should scrutinize the role and quality of RECs and other environmental attribute certificates in corporate emission reduction claims and strategies for future emission reductions. This would be in line with recent coverage in mainstream and finance media showing that a critical awareness around RECs and scope 2 accounting rules is emerging (Washington Post 2023, Bloomberg 2024, Financial Times 2024, The Guardian 2024).

5. Conclusion

We find that a substantial fraction of companies that currently appear to be ahead on their climate targets would fall behind under stricter scope 2 accounting rules. This finding can inform the development of future accounting standards, including the revision of the GHG Protocol and emerging standards around renewable fuels.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

Conflict of interest

The first author is a remunerated member of the Technical Council of the Science Based Targets initiative. The remaining authors declare no competing interests.

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