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Exploring the effect of Guarantees of Origin on the decarbonization of corporate electricity procurement

A case study of Germany and Norway

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Abstract

Increasing social, economic, and political pressure causes many companies to pledge to decarbonize. A common measure involves the use of Energy Attribute Certificates (EAC), such as the European Guarantees of Origin (GO), to reduce emissions from electricity procurement (Scope 2). However, previous studies find no effect on additional renewable energy capacity. Focusing on Norway and Germany as dominant contributors to net GO exports and imports, this study examines the GO trade alongside corporate carbon accounting data to answer the research question: Does the decarbonization of corporate electricity procurement using Guarantees of Origin contribute to the expansion of renewable electricity generation capacity in Norway and Germany? The analysis of CDP and Association of Issuing Bodies data reveals Norway's consumption mix is more carbon intensive than Germany's because Norway exports GO and imports fossil electricity attributes. German companies report predominantly market-based approach, mainly using green tariffs and GO for zero emission claims, while Norwegian companies favor the location-based approach. The largest share of GO issued in Norway comes from hydropower plants aged 41 to 70 years. The results highlight the urgency to revise corporate carbon accounting standards. GO lack additionality due to double counting of renewable attributes. Potential solutions include additionality criteria, GO trade restrictions based on physical capacities, and age limits for eligible power plants. This study's novelty is linking CDP data with GO trade, to assess the integrity of corporate decarbonization strategies. It contributes valuable insights to ongoing discourse on the role of EAC.

KEYWORDS
carbon accounting, Energy Attribute Certificates, energy transition, green electricity procurement, industrial ecology, renewable energy

1 INTRODUCTION

The energy sector is the largest contributor to climate change with about 34% of global greenhouse gas emissions (GHGE) in 2019 (Dhakal et al., 2023). Within this sector, electricity plays a pivotal role, constituting approximately 36% of the total emissions (Clarke et al., 2023). The largest share of electricity consumption is connected to companies. In 2019, only 27% of worldwide electricity consumption happened in the residential sector (IEA, 2023).

1.1 Motivation

Increasing social, economic, and political pressure, for example, in the form of the European corporate sustainability reporting directive (Corporate Sustainability Reporting Directive, 2022), has caused many companies to pledge to decarbonize their operations. As of June 2023, 929 out of the world's 2000 largest public companies have set net-zero targets, more than twice as many as in December 2020 (Net Zero Tracker, 2023). Furthermore, over 7900 companies have either submitted or are planning to submit targets to the science-based targets initiative (SBTi, 2024).

The leading standard for corporate carbon accounting, the greenhouse gas protocol (GHGP), differentiates three areas for accounting (WRI & WBCSD, 2004): Scope 1, which refers to direct emissions from sources owned or controlled by the company, such as from energy generation on company premises; Scope 2, which includes "emissions from the generation of acquired and consumed electricity, steam, heat, or cooling" (WRI & WBCSD, 2015); and Scope 3, which comprises of all other indirect emissions up- and downstream. Emissions from upstream activities of energy providers, for example, mining of coal, belong to Scope 3 (WRI & WBCSD, 2004).

A significant part of most company's GHGE comes from the procurement of energy, mainly electricity, in Scope 2. Reducing emissions from electricity consumption requires either increasing energy efficiency or the use of renewable energy.

Physically tracing one's grid electricity consumption to the supply is impossible. In practice, many companies rely on Energy Attribute Certificates (EAC) to claim a decarbonized electricity supply (Bjørn et al., 2022). EAC can be bundled, meaning that the attribute is bought and supplied in combination with the physical electricity, or unbundled, meaning that the attribute is dealt with completely independently from the physical electricity. In the remaining paper, "EAC" refers to unbundled units.

The GHGP allows to account for electricity covered with EAC with zero emissions (WRI & WBCSD, 2015). The GHGP is mandatory to use following European legislation on corporate sustainability reporting (European Commission, 2023). EAC are also accepted by the SBTi as measure to reduce GHGE in accordance with the 1.5°C goal of the Paris agreement (SBTi, 2021).

This attributional approach, however, does not inherently guarantee a contribution to both national and global climate change mitigation objectives. What matters in the end is the additional installation of renewable energy capacity and the subsequent displacement of fossil-based electricity generation. Without additionality, the procurement of green electricity amounts to a mere claim of renewable attributes.

1.2 Literature review and research gap

The GHGP justifies the unconditional recognition of EAC based on the assumption that an increase of demand will be followed by an increase in supply and thus additionality (WRI & WBCSD, 2015). However, various studies examining the impact of EAC on the addition of renewable energy capacities have reported either no effect or negligible influence.

Brander et al. (2018) argue that the market-based method, rooted in contractual agreements, lacks efficacy in promoting additionality. They highlight the abundance of existing renewable generation, high costs associated with genuinely additional supply, the elasticity of demand, and that renewable attributes from subsidized energy can still be marketed. This aligns with the findings of Gillenwater et al. (2014), derived from a spatial financial model, which contest the contribution of EAC to the economic feasibility of wind power plants in the United States.

Hulshof et al. (2019) analyze the performance Guarantees of Origin (GO) markets, the EAC system of the EU, in 20 European countries over 2001 to 2016. Their analysis reveals low market liquidity, heightened price volatility, and a persistent oversupply leading to subdued GO prices.

Hamburger and Harangozó (2018) analyze the effect of different factors on the expansion of renewable energy in the EU. They conclude that GO have no significant impact on additionality. A study by the German Environment Agency reinforces this standpoint, indicating that GO constitutes a minuscule share of operator revenues (Hauser et al., 2019).

This is in line with the results of Mulder and Zomer (2016), who identify a low additionality effect of renewable electricity labeling in the Netherlands. They attribute this to the supply with low-priced GO from Norway, where the marginal costs of GO are negligible due to low domestic demand. Herbes et al. (2020) investigate the supply side of green retail electricity products in the United Kingdom, Italy, Germany, and France. Their content analysis suggests that hydropower from Scandinavia or Austria dominates the products, with limited potential for inducing additionality, except in the United Kingdom.

TABLE 1 Total sample sizes for the analyzed questions for all Association of Issuing Bodies domains (CDP, 2023) and share of companies that answered question C7.9b and report according to Greenhouse Gas Protocol.

Year	C7.5	C7.9b	C7.9b—Share of GHGP	C8.2e / C8.2h
2020	3946 sites market based, 4619 sites location based	648 companies	81%	886 sites
2021	4861 sites market based, 5533 sites location based	792 companies	82%	2925 sites
2022	6178 sites market based, 6829 sites location based	954 companies	87%	5019 sites

Other studies criticize the trade with EAC, in particular GO, for not representing physical boundaries of electricity trade. Hamburger (2019), analyzes GO trade from 2016 to 2018, comparing it with physical electricity flows. He concludes that traded attributes far exceed physical capacity, causing low prices in certain countries and rendering GO ineffectual. Similar conclusions are reached by Bogensperger and Zeiselmair (2020).

Klimscheffskij et al. (2015) show why reliable electricity disclosure systems require explicit (e.g., EAC) and implicit disclosure systems to prevent double counting of explicitly tracked attributes in the energy mix. Holzapfel et al. (2023) discuss challenges for life cycle assessment and greenhouse gas (GHG) accounting regarding double counting of electricity attributes caused by market-based accounting and potential solutions.

Monyei and Jenkins (2018) criticize corporations, in particular Google and Apple, for claiming to be supplied with renewable electricity only as this might conceal the complexities of energy transitions, for example, simultaneity of power supply and demand.

A primary critique within the existing literature centers on double counting of renewable electricity attributes, a phenomenon ascribed to the combined effects of the current reporting standards of the GHGP and the trade of EAC (Bjørn et al., 2022; Holzapfel et al., 2023).

The GHGP defines two options for accounting for emissions from electricity in Scope 2: the location- and market-based approach (WRI & WBCSD, 2015). The location-based method mandates the use of average emission factors derived from the region or country in which the company operates, typically reflecting the national electricity grid mix. In contrast, the market-based method derives emission factors from the specific procurement choices made by a company, such as opting for a green electricity tariff. The GHGP prescribes a prioritization for the choice of emission factors in the following order: EAC, contracts, supplier/utility emission rates, residual mix, and other grid-average emission factors (WRI & WBCSD, 2015). In regions with an electricity disclosure system, such as GO in the EU, companies must report emissions from both approaches. Nevertheless, when it comes to reporting their Corporate Carbon Footprint (CCF), companies have the flexibility to choose either approach, provided they maintain consistency across reporting periods.

For companies in countries with a high share of low-carbon electricity generation, using the location-based method is beneficial, while for companies in countries with a fossil-dominated electricity mix, the market-based method is advantageous. Consequently, a single renewable attribute can be utilized by two companies, provided they adhere to distinct accounting approaches. The other important standard for corporate carbon accounting, the ISO 14064, prescribes the use of the location-based method, but allows to report the market-based account as additional information (ISO, 2018).

In this study, we focus on the GO system in the EU for two main reasons: (a) data availability, (b) the EU's ambitious European GHG reduction targets (European Commission, 2019) as well as historic responsibility for GHGE, and (c) because it is a long existing and well-established EAC system. It was established with the EU Directive 2001/77/EC (Renewable Energy Directive, 2001) as a market-based mechanism to incentivize the production of electricity from renewables. Member states are mandated to issue GO for each megawatt-hour (MWh) electricity generated from renewables upon request by the producer. However, member states can decide not to issue GO if the producer is already benefiting from other forms of national support, such as a feed-in tariff. Some countries implement further conditions, such as export restrictions (Hulshof et al., 2019). GO may also be issued for non-renewable energy (Renewable Energy Directive, 2018). In this study, however, we decided to focus on renewable electricity because of its volume compared to other forms of energy. In 2022, renewable electricity GO accounted for 69% of issued and 76% of exported GO in Europe (AIB, 2023c). When addressing GO or Scope 2 in the following, we are referring exclusively to GO from renewable electricity. GO can be transferred independently from the physical electricity and used by retailers to label electricity as "green." This detachment results in the loss of the "green" attribute for the renewable electricity for which the GO is initially issued. GO are traded within and across 28 European countries (AIB, 2023a). Each country manages at least one GO register through a designated responsible, all of which are unified in the Association of Issuing Bodies (AIB). Once a GO is used, it is cancelled within the administrative system, preventing double use. GO expire after 1 year after issuance. In 2022, GO were issued for 56% of the 1040 terawatt-hours (TWh) of renewable electricity produced in the EU (AIB, 2023c; Council of the European Union, 2023).

In Table 1 in Supporting Information 4, the content of the scientific literature as well as the data basis presented before is illustrated with regard to five criteria: (1) considering the European trade of GO in contrast to similar systems, (2) referring to and analyzing CDP data, (3) examining additionality of the considered system regarding the expansion of renewable energies, (4) examining double counting of certificates, and (5) quantifying this double counting.

It shows that there is no literature or data basis that considers all five mentioned criteria. We aim to fill this research gap and contribute to the existing literature by quantifying the alleged double counting caused by firms using the market- and location-based approach. We achieve this by synthesizing GO trade data with company reporting. We focus on the implications of the GO trade, without going into more detail on the other general problems of EAC, for example, the double counting of EAC as explicitly tracked (market-based) and part of the energy mix (location-based) within one domain (Holzapfel et al., 2023; Klimscheffskij et al., 2015).

As shown in the results section, Norway and Germany dominate the GO trade in Europe, as net exporter and net importer, respectively. Therefore, we decided to mainly focus on those two countries as examples to illustrate the issues with the GO system as it is.

Our research question is: "Does the decarbonization of corporate electricity procurement using Guarantees of Origin contribute to the expansion of renewable electricity generation capacity in Norway and Germany?"

This paper is structured as follows: first, a concise description of the data sources and methods; second, the presentation of the results; and in the end, a discussion encompassing limitations, implications, and potential solutions within the context of the existing literature.

2 | METHODS

To answer the research question, we analyze the status quo of GO trade and Scope 2 reporting of companies within AIB domains. In the following, we briefly describe the two main data sources and approach to analyzing the data.

2.1 | Data on Guarantees of Origin trade

The first, provided by the AIB, is publicly available and contains aggregated statistics for the transactions of GO per country (AIB, 2023c). These transactions include the monthly (since 2016) and yearly issuance, cancellation, expiry, export, and import of GO by domain. Cancellation is divided into own domain and ex-domain, making it possible to understand how many GO issued in a specific country are not cancelled in the same. Furthermore, the data include the energy source of the GO, but not the specific plant. Notably, the data lacks granularity regarding bilateral trade details, such as the parties involved. Some national registers, such as the Norwegian one (Statnett, 2023a), do offer such information, but achieving a comprehensive overview is not possible with the publicly available data.

The dataset was retrieved on June 9, 2023. The data were first cleaned to only include GO from renewable electricity production (category "mechanical/other"). The data for the four Belgian domains were aggregated. The total imports and exports as well as issue and cancel transactions since 2013 were extracted and analyzed. The processed data can be found in Supporting Information 2 while the cleaned data is provided in Supporting Information 3.

2.2 | Data on corporate carbon accounting

The second data source is the climate related "Corporate response dataset" provided by the CDP (formerly Carbon Disclosure Project). This dataset comprises self-reported environmental data from more than 8000 companies for the reporting years from 2020 to 2022 in the form of a questionnaire (CDP, 2023). This temporal delineation was chosen due to the lack of feasibility in linking sourcing strategies, which are the base of zero emission electricity claims, with AIB domains before 2020. The data is available under license only. The aggregated results of the analyzed data can be found in Supporting Information 4 and are given as percentage share.

The questionnaire includes information such as corporate emissions, applied reporting standards, energy use as well as metadata like company size and industry. Most questions contain multiple datapoints. Three questions of the questionnaires were analyzed. They ask for the total Scope 2 GHGE by company site and accounting approach—market- and location-based approach need to be distinguished—(C7.5), the chosen accounting approach for the overall CCF (C7.9b), and details on renewable electricity purchases such as sourcing method, technology type, and commissioning year of the facility by company site (C8.2h). Companies were assigned to AIB domains based on their headquarter location, whereas company sites were assigned based on their location.

The answers to question C7.5 were used to calculate the arithmetic mean of GHGE by company site, Scope 2 accounting approach and AIB country. Based on question C7.9b, the number of companies calculating their CCF based on the market- or rather location-based approach was determined per AIB domain and year.

Questions C8.2e and C8.2h were only applicable for companies that report according to the market-based accounting approach as details on renewable electricity purchases are irrelevant if the location-based approach is used. For 2022, question C8.2e was split into C8.2e and C8.2 h, with the latter being specifically for companies that are RE100 members. Thus, both were included in the analysis for 2022. For the analysis, first, all *not applicable* answers and companies or sites not located in an AIB domain were excluded. For this, the country of consumption was considered because the area in which GO are used for zero emission claims is of interest. Second, all answers not referring to electricity but to heat, steam, or cooling were excluded from the analysis. Third, all companies or sites whose location could not be uniquely connected to an AIB domain, for

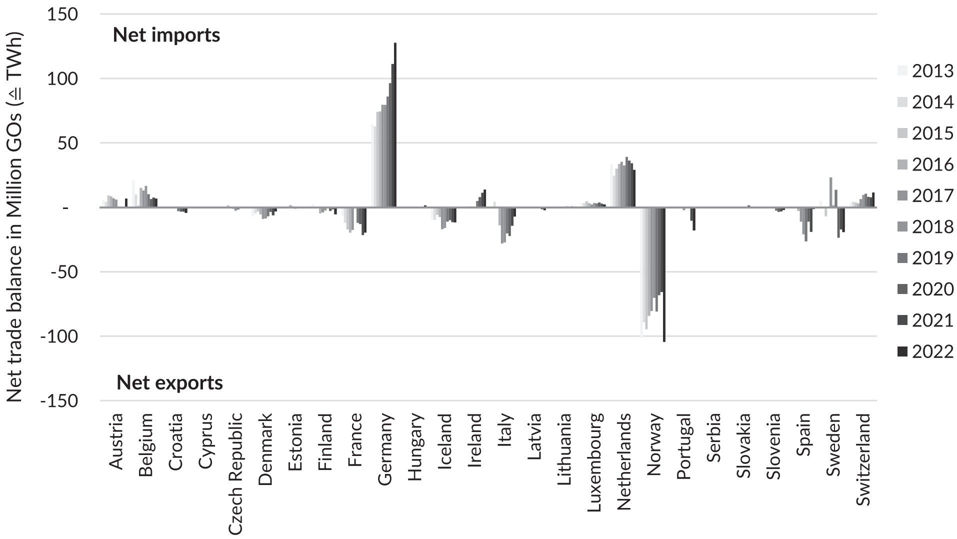

FIGURE 1 Guarantees of Origin net imports and exports per domain from 2013 to 2022 (data from AIB, 2023c). Greece and Montenegro issue GO, but do not provide data to the Association of Issuing Bodies. Thus, they are excluded. The data for the four Belgian certifying organizations was aggregated. For years before 2016, the share of hydropower is not available from the data. Underlying data for this figure are available in Supporting Information S2.

example, *Other: Central Europe*, as well as companies or sites not specifying their sourcing method for renewable energy were removed from the total dataset. Fourth, the answers referring to the sourcing method were classified as follows: *Green Tariffs & GO*, *Default renewable electricity from grid*, *PPA*, and *Self-generation*. In this regard, answers with a sourcing method that could not be clearly classified, for example, *Other, please specify: Various*, were removed and therefore excluded from the analysis. Lastly, outliers were excluded if the provided information clearly contained errors.

The sample size varies per question because answering the questionnaire is voluntary. Table 1 shows the sample sizes for the analyzed questions. Detailed methods of carbon accounting are not disclosed by the companies. However, most companies report according to the GHGP (WRI & WBCSD, 2004).

3 | RESULTS

3.1 | Effects of net imports and exports of renewable energy Guarantees of Origin

Figure 1 shows the net imports and exports of renewable energy GO for all members of the AIB from 2013 to 2022. Norway and Germany in particular stand out while most countries have much lower net imports and exports. Germany shows increasing net imports, Norway decreasing net exports between 2013 and 2021 with sudden strong increase in 2022.

Together, Germany and Norway make up for 58% of the net imports and exports of 2022, which is why we decided to examine both in more detail. Norway is particularly special as it is not only the main exporter of GO but also acting as a major trading hub for GO (Hauser et al., 2019). Additional results including all AIB domains can be found in Supporting Information 1.

Figure 2 shows the transactions of GO for renewables in Norway and Germany from 2013 to 2022 and the respective share of hydropower. Germany imports significantly more GO than are issued domestically. Norway issues more GO than it cancels due to the large net export. Norway alone makes up for 24% of all GO issued in 2022. Physically, Norway exported only 17.67% of its electricity production in 2022 (Statistics Norway, 2023). The net exported GO were equivalent to 71.26% of the electricity production (AIB, 2023c). Additionally, all transactions show an increasing trend over the years. Particularly interesting is the large share of hydropower in all transactions, especially in Germany despite its low contribution of only 7% to domestic renewable electricity generation in 2022 (German Environment Agency, 2023).

The trade balance of Norway and Germany is also represented in the production, residual, and supplier mix of both countries. Those are three different emission factors used to show the effects of trade with electricity attributes throughout Europe. They are published yearly by the AIB (2023b) following the methodology defined by Kuronen et al. (2020). The production mix represents the emission intensity of domestic electricity production (territorial), without accounting for GO or other attribute tracking instruments. The residual mix covers the electricity attributes that are not tracked by GO or other tracking mechanisms that the AIB considers reliable (e.g., feed-in-tariff systems). For this purpose, all electricity

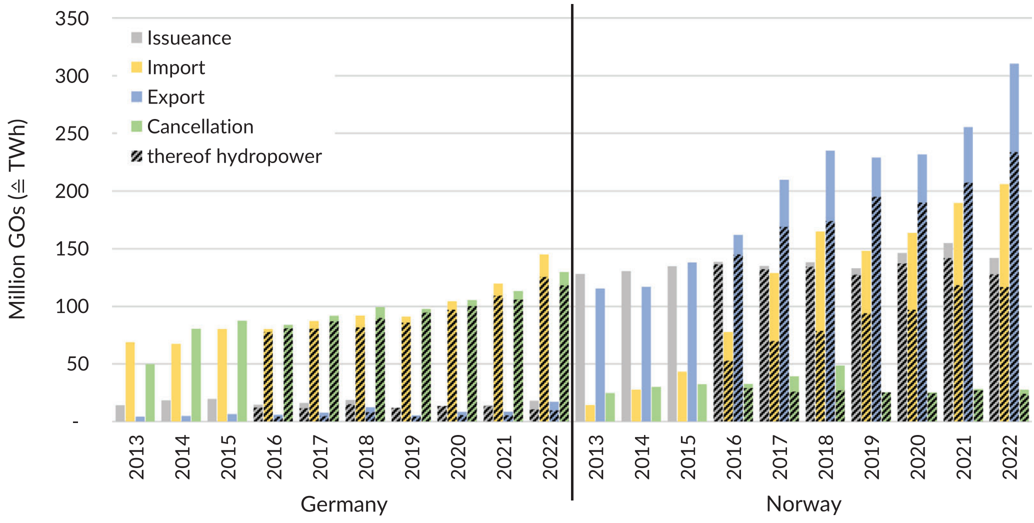

FIGURE 2 Guarantees of Origin (GO) transactions in Germany (left) and Norway (right) from 2013 to 2022 (data from AIB, 2023c). The share of hydropower is displayed as hatched area. For years before 2016, the share of hydropower is not available from the data. Because GO must not be used immediately, the balance can be uneven within single years. Moreover, GO are often imported and exported again in the same year. Underlying data for this figure are available in Supporting Information S2.

TABLE 2 Production, residual, and supplier mix for Norway and Germany in from 2020 to 2022 (AIB, 2021, 2022, 2023b). The Association of Issuing Bodies changed its methodology in 2020, limiting the comparability with prior years.

Year	Domain	Production mix (gCO_2/kWh)	Residual mix (gCO_2/kWh)	Supplier mix (gCO_2/kWh)
2020	Germany	339	589	184
	Norway	8	402	318
2021	Germany	378	618	240
	Norway	4	405	309
2022	Germany	388	684	186
	Norway	7	502	409

quantities for which explicit traceability exists are deducted from the production mix. The supplier mix is the total electricity attribute consumption by a country. It shows the emission intensity of electricity consumption after allocating all traceable and untraceable electricity attributes of the participating countries.

Due to a change in methodology since the calculation for 2020, comparing the residual mix with years prior is only possible to a limited extent. Thus, we show the production, residual, and supplier mix for Germany and Norway for 2020 to 2022 in Table 2. Despite partially significant changes over the years, the general relationship of the factors within and between Norway and Germany holds.

As can be seen, the production mix of Germany was between 339 and 388 gCO_2/kWh while the Norwegian electricity production is largely decarbonized due to the high share of renewable energy (Statistics Norway, 2023). Both countries show a large disparity between the production and residual mix. This is because renewable electricity is largely covered by reliable tracking systems in both cases, leaving only fossil energy for the residual mix. In Germany, about 95% of the installed renewable energy capacity is subsidized with a feed-in-tariff (Bundesnetzagentur, 2021, 2022), which the AIB classifies as a reliable tracking system. In Norway in 2022, GO were issued for 97% of the generated electricity (Statistics Norway, 2023).

The supplier mix of Germany is less carbon intensive than the residual and production mix because the "green" attributes of the subsidized electricity get no GO issued and cannot be exported. Thus, a large quantity of GO is imported by businesses and consumers, leaving only a small amount of fossil electricity attributes in the supplier mix. Norway, in contrast, has a more carbon intensive supplier mix because a large share of renewable attributes is exported as GO. It exports "green" electricity attributes in the form of GO and imports fossil electricity attributes for the consumption mix from the rest of Europe. Nevertheless, Norwegian consumers perceive their electricity to be renewable as it is (Winther & Ericson, 2013). Furthermore, interviews with Norwegian company representatives show that the same notion exist within firms, causing them to have no interest in buying GO (Aasen et al., 2010).

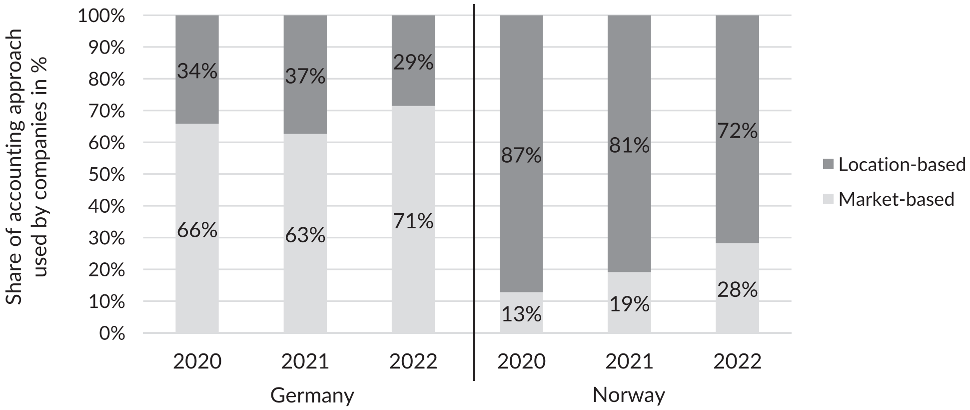

FIGURE 3 Share of electricity accounting approaches by companies in Germany and Norway reporting to the CDP between 2020 and 2022 (data from CDP, 2023). The sample sizes for Germany are: 133 in 2022, 99 in 2021, and 82 in 2020. The sample sizes for Norway are: 46 in 2022, 47 in 2021, and 39 in 2020. Underlying data for this figure are available in Supporting Information S4.

TABLE 3 Mean global greenhouse gas emissions reported by Norwegian and German company sites for the location- and market-based methods for 2020 to 2022 (data from CDP, 2023).

Year	Domain	Mean GHGE reported location-based in tCO_2e	Mean GHGE reported market-based in tCO_2e
2020	Germany	59,438 (sample size: 508)	48,334 (sample size: 430)
	Norway	3294 (sample size: 163)	24,898 (sample size: 140)
2021	Germany	45,363 (sample size: 607)	40,757 (sample size: 526)
	Norway	2957 (sample size: 202)	20,499 (sample size: 180)
2022	Germany	35,413 (sample size: 739)	28,738 (sample size: 663)
	Norway	2383 (sample size: 239)	17,986 (sample size: 226)

Note: The sample size includes the number of company sites with answers in AIB domains. Underlying data for this table are available in Supporting Information S4.

3.2 | Quantity of companies using location-based and market-based accounting

Figure 3 shows that German companies within the CDP dataset report predominantly market-based approach while Norwegian companies mostly use the location-based approach. However, at least from 2020 to 2022 there is an increasing trend of reporting market-based in Norway.

While the CDP questionnaire refers to whole companies for the accounting approach, the data for the reported emissions by approach are resolved to site level. Table 3 shows the mean GHGE reported by Norwegian and German company sites for each accounting method. The data shows that for Norwegian sites, the mean location-based emissions are much lower than the market-based ones, while for Germany it is the opposite.

Figure 4 shows the share of different sourcing methods for renewable energy for production sites in Germany and Norway from 2020 to 2022 that is the basis for reporting zero emissions following the market-based approach. For German sites it clearly shows a dominance of green tariffs and GO as the basis for the claim of zero carbon electricity over all years. The shares for Norway differ substantially between the years with 2020 being dominated by power purchase agreements (PPA), green tariffs and GO; 2021 by green tariffs, GO, and claims of renewable attributes from the default grid mix; and 2022 dominated by green tariffs and GO while PPA and the grid mix are of similar importance. The fluctuations are likely due to the small sample size for Norwegian sites and frequent changes in participating sites. The samples for Norway and Germany together account for 42,975,881 MWh of claimed green electricity procurement in 2022 (31,102,674 MWh in 2021 and 17,786,434 MWh in 2020). Important to keep in mind is that most Norwegian companies report location based (see Figure 3).

Of the total sample size of 5019 sites in the AIB countries in the 2022 questionnaire, which accounts for 169,352,983 MWh reported renewable electricity, 70% are based on GO. GO are thus the dominant tool used by companies to claim a renewable electricity procurement.

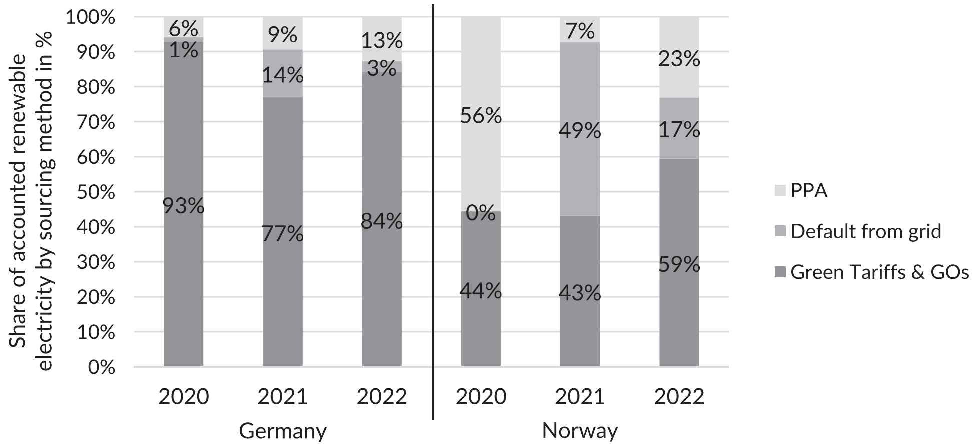

FIGURE 4 Share of sourcing method for renewable energy reported to the CDP by production site between 2020 and 2022 (data from CDP, 2023). The sample sizes for Germany are: 717 in 2022, 349 in 2021, and 130 in 2020. The sample sizes for Norway are: 166 in 2022, 103 in 2021, and 26 in 2020. Answers including green tariffs and GO were aggregated. Underlying data for this figure are available in Supporting Information S4.

3.3 | Limiting additionality of Guarantees of Origin for Norwegian power plants

Lastly, Figure 5 shows the age distribution of Norwegian wind and hydro power plants approved for GO by estimated yearly production. Wind and hydro account for 99.84% of renewable electricity GO issued in 2022. The largest share of GO issued in Norway comes from hydro power plants that are between 41 and 70 years old. The mean age weighted by production is 49 for hydro and 5 for wind. The underlying data can be found in Supporting Information 5.

Due to the high age of the plants and the low level of new construction in hydropower, additionality is limited when purchasing GO from Norway. This and the market surplus of GO mean that only the place of devaluation changes, but no additional energy from renewable energies is produced through the purchase of GO. This effect becomes clear in the comparison of the production, residual, and supplier mix for Norway and Germany as described in Section 3.1.

4 | DISCUSSION

4.1 | Limitations

The main limitation of this study is the data. In the past, irregularities like incomplete reporting, were observed in AIB data (Hulshof et al., 2019). This potential shortcoming was not systematically addressed in our analysis. The AIB dataset furthermore lacks information on bilateral trade details, which may conceal important dynamics.

Concerning CDP data, the accuracy of self-reported information remains uncertain. The CDP does not require verification by third parties. Stanny (2018) scrutinized CDP data from US utility companies and discovered inconsistencies in reporting boundaries and accounting methodologies, that might also be present for other industries and regions. Furthermore, while it is a large dataset, the representativeness of these companies to the broader population of global companies or within the AIB domains might be a concern, for example, due to a bias toward predominantly large international companies reporting to the CDP.

Our study also entails limitations in terms of sample sizes for the CDP data, particularly for Norwegian companies. A further limitation concerns the availability of longitudinal data. Due to the described changes in the CDP questionnaire over the years, the tracking instrument used for renewable electricity instruments is only disclosed since the 2020 questionnaire.

4.2 | Implications

Our results show that the decarbonization of corporate electricity procurement using Guarantees of Origin currently does not have an additionality effects in Norway or Germany.

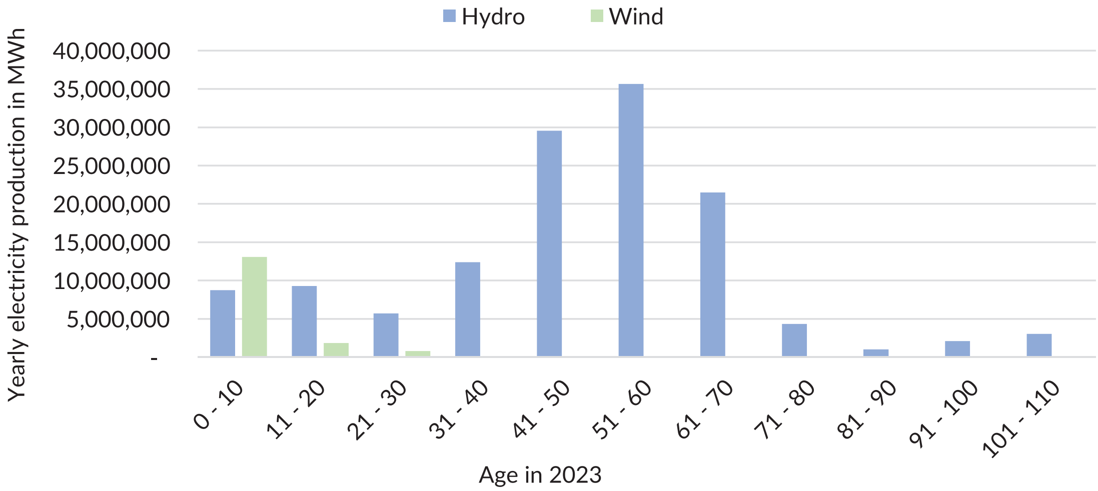

FIGURE 5 Age distribution of Norwegian electricity generation capacity eligible for Guarantees of Origin in 2023 (data from Statnett, 2023b). Only hydro and wind energies are displayed because they make up for 99.84% of the estimated yearly electricity production. Underlying data for this figure are available in Supporting Information S5.

Due to the Scope 2 accounting rules of the GHGP the same GO are accounted for multiple times. This occurs as companies selectively choose the accounting approach that minimizes their CCF. The oversupply, that is a consequence of double counting, is also reflected in low prices Europe wide (Wimmers & Madlener, 2020). We conclude that, currently, GO primarily serve as an additional revenue stream for aging hydropower plants in Scandinavia.

As long as low-priced supply from Norway and other regions dominates the GO market, a significant additionality effect of the European GO system on the expansion of renewable energy can be ruled out. The idea to foster the expansion where it has the lowest cost is limited by the fact that Norway's electricity generation is already renewable (Statistics Norway, 2023) and transmission capacity to the rest of Europe is finite. Furthermore, Norwegian firms (Aasen et al., 2010) and consumers (Winther & Ericson, 2013) consider their electricity renewable in any case. While the European context is unique, our findings have broader relevance for any EAC market with substantial differences in marginal EAC costs and average grid emissions, such as the United States.

Besides the lack of additionality, there is a risk of lock-in effects. The use of GO may allow utility companies to delay necessary transformations, selling "green" electricity while concurrently installing new fossil fuel plants. This situation may also discourage energy efficiency measures, as they do not contribute to reducing the carbon footprint once the electricity consumption is accounted for with zero emissions (Holzapfel et al., 2023).

Apart from the slowing effect on the energy transition, the current situation poses risks to companies who use GO to decarbonize their electricity procurement. Foremost among these risks is the potential for changing accounting rules or a sudden shift in supply, for example, if Norway exited the GO system. This is currently unlikely because of new legislation coming in place (Clausen, 2023). However, it has been part of the government's plans in the past (Energi Danmark A/S, 2021). Furthermore, the GHGP is currently revising all corporate standards, with a focus on Scope 2 emissions accounting (WRI & WBCSD, 2023a). These rules could become even more crucial for companies in the future, as the GHGP serves as one basis for the new international standard on carbon neutrality, ISO 14068, published in November 2023 (ISO, 2023). In such a case, companies relying on renewable energy for decarbonization targets would face significant financial and reputational risks. Conversely, the dependence of companies on GO indicates a significant potential for corporate engagement. Bjørn et al. (2022) show how much corporate climate mitigation targets depend on EAC.

Another implication of the missing additionality is its connection to other legislation. The European Commission has designated GO as a method for substantiating claims related to the utilization of renewable energy in alignment with both sustainability reporting and the EU Taxonomy. According to Annex 1 of the recently established European Sustainability Reporting Standards, claims pertaining to renewable electricity must be substantiated by contractual arrangements, with GO being one of the preferred options (European Commission 2023). Consequently, companies can leverage GO to reduce their capital costs, despite GO not contributing to a reduction of GHGE.

A similar issue applies to national support schemes. Germany, for example, supports the development of decarbonization strategies financially. One of the measures that can be credited is the procurement of a GO-based green electricity tariff (BMWK, 2022). Thus, there is no incentive for firms to invest in genuine additionality, for example, in form of on-site renewables or PPA.

Finally, the issue of double counting also has implications for other carbon accounting methods. The implications for life cycle assessment in particular are discussed by Holzapfel et al. (2023).

4.3 | Potential solutions and outlook

One solution to reduce oversupply could be a general ban on issuing GO for already subsidized renewable capacity, taking inspiration from Germany's approach (Gesetz für den Ausbau erneuerbarer Energien, 2023). As national subsidies are usually finance from taxes or consumer levies, emission reduction should be attributed to the collective contributors rather than individual companies merely paying the nominal cost of a GO. This becomes especially crucial as the ongoing expansion of renewable energy will increase the supply in the future (Brander et al., 2018).

Other suggestions include limiting cross-border trade with GO to realistic physical flows (Bogensperger & Zeiselmair, 2020; Hamburger, 2019), requiring GO to be issued in the same grid as the consumption occurs (Robinson & Sullivan, 2022) and making accounting with the residual mix mandatory for the location-based approach (Hamburger, 2019). The latter would prevent double counting as attributes already accounted for market-based approach would be excluded from location-based accounts. A likely consequence of this adjustment could be Norwegian companies opting to purchase GO, potentially leading to an increase in prices.

However, whether a decrease of GO supply will lead to significant additionality remains uncertain. The decreasing supply might be offset by existing renewable power plants that have abstained from GO issuance thus far (Hauser et al., 2019). Furthermore, many consumers, especially households, neither disclose their emissions nor opt for the purchase of renewable electricity (Bjørn et al., 2022). To compensate for reduced supply, there might be a shift of renewable attributes from those to the demanding actors. Ultimately, the goal of a GHG-neutral electricity system through a purely market-based approach could only be achieved if all consumers demanded GHG-neutral electricity. Up to that point, a switch to renewable electricity will only contribute additionality equivalent to the difference of demand and supply (Brander et al., 2018).

Hence, some authors discuss abolishing the market-based method in favor of mandating the location-based approach (Brander & Bjørn, 2023). This would prevent double counting and attribute switching. The location-based method might also incentivize companies to local engagement and advocate for grid transformation (Bird et al., 2021). However, only allowing location-based accounting might disincentivize company investments in renewable energy capacity (Bjørn et al., 2022).

Other options would be limiting the age up to which power plants are eligible for GO, as suggested by Jansen (2017) and Mulder and Zomer (2016), or moving to a more consequential accounting (Brander & Bjørn, 2023). This might entail using marginal emissions for consumption and marginal avoided emissions from generation, as proposed by He et al. (2021). This could be amplified by state-led labeling schemes setting minimum requirements for green electricity products (Herbes et al., 2020).

Currently, there is no indication that the EU will make significant changes to the GO system. In fact, the recently adopted new EU Renewable Energy Directive did not implement significant changes to the current system, apart from mandating member states to issue GO for gaseous renewable fuels of non-biological origin (Renewable Energy Directive, 2023).

A promising development is the ongoing revision of the GHGP (WRI & WBCSD, 2023a), with one focus being Scope 2 accounting. The revision commenced with a stakeholder survey. Preliminary results for Scope 2 exhibit a lack of consensus on a specific solution. Proposals range from incorporating additionality criteria and committing to one accounting approach to specifying granular time and location criteria for renewable electricity claims (WRI & WBCSD, 2023b). The GHGP aims to conclude the revision by 2025 (WRI & WBCSD, 2023a).

Notably, changes to the GHGP could yield direct impacts, such as demanding proof of additionality or prohibiting the use of unbundled EAC, distinguishing it from measures targeting supply and demand for EAC.

Looking ahead, time granularity might become an important factor, given the intermittency of renewable energy. A consideration over a 1-year balance period may prove insufficient (Chalendar & Benson, 2019). Some companies, such as Google, aspire to maintain a GHG-neutral electricity supply throughout the day (Google Data Centers, 2023).

Time granularity is also relevant for location-based accounting. Miller et al. (2022) show that for the US calculating emissions from electricity consumption on an hourly basis can make up to 35% differences in carbon inventories and recommend to use hourly accounting for the location-based approach. Spork et al. (2015) similarly advocate for real-time data utilization, highlighting significant errors in GHG inventories when relying on yearly averages.

Finally it is crucial to acknowledge the substantial impact that corporate procurement strategies may exert on grid operations and planning (O'Shaughnessy et al., 2021). This impact could be particularly relevant if companies currently relying on GO transition to methods with higher additionality, such as PPA. While facilitating corporate engagement and investments in the energy transition is vital, it does not substitute for central planning required to ensure an efficient transition.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The publicly available data supporting the findings of this study are available in the Supporting Information. Restrictions apply to the availability of the CDP data, which were used under license for academic research. Reproduction of any part of the data by any third party is forbidden. They are available from the CDP.

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