CARBON ACCOUNTING OF ELECTRICITY: MANAGING THE GAP BETWEEN MARKET- AND LOCATION-BASED APPROACHES

DISCUSSION PAPER

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About this discussion paper

Hamburg Institut has been providing research and consulting services in the fields of climate change mitigation and energy system transformation since 2012 with an interdisciplinary team of experts. Both in our daily research and project work with our customers and in our participation in national, European and international standardisation processes, we keep addressing questions related to certification systems and carbon accounting.

A much-discussed topic is the **gap between the market-based and the location-based approach to** handling emissions from electricity purchases. In their current design and practical application, the parallel use of the two approaches represents an obstacle to comparability and, consequently, to the credibility of carbon accounting as a whole.

With this paper, we would like to shed more light on the current issues – but above all, we would like to **encourage discussion on possible solutions** and emphasise the need to harmonise the existing approaches to electricity accounting.

KEY TAKEAWAYS

In greenhouse gas (GHG) inventories of companies and products, the emission factors of purchased energy, especially electricity, make up a significant proportion. In this respect, it is of particular interest to companies to procure as much green electricity as possible with a low emission factor and to take this into account as effectively as possible in their GHG accounting. With the market-based and the location-based approach, there are different accounting methods that lead to different results. This poses challenges for companies, accounting standards and legislators alike.

INITIAL SITUATION AND CHALLENGES

- **Non-harmonised accounting methods**:
  As guidelines leave scope for interpretation, many companies decide in favour of the accounting principle that promises them the lowest footprint when accounting for purchased electricity.

- **Risk of double counting**:
  The parallel application of two approaches to accounting for electricity in the carbon footprint can lead to double counting of renewable energy attributes. This harbours the risk of overestimating environmental impacts and preventing the comparability of GHG inventories (CCF & PCF).

- **Loss of credibility**:
  Overall, the credibility and informative value of carbon footprints suffers when different methods are used within sectors and value chains to calculate emissions from electricity consumption.

- **Physical reality cannot currently be depicted**:
  Neither the market-based nor the location-based approach in its current form and practice fulfils the frequently stated requirement that the method that most closely reflects physical reality should be selected.

PROPOSED SOLUTIONS

- **Consistent application of <u>one</u> accounting approach**:
  In order to avoid double counting of renewable energy attributes when calculating emission factors, only one accounting approach should be consistently applied – if possible across the entire value chain. There is a need to harmonise electricity accounting methods along the value chain and within sectors.

- **Prioritised application of the market-based approach**:
  In electricity markets with a stable, resilient and transparent renewable energy verification system based on energy attribute certificates (e.g. guarantees of origin), market-based accounting should be used. Only a market-based approach would therefore be permissible in the EU electricity market.

- **Location-based approach only in regions without or with an unreliable renewable energy verification system**:
  In regions without an adequate renewable energy verification system, the location-based approach should be used to determine the emission factors.

- **Understanding and applying the market-based approach as a pure recording tool, to begin with:**
  Renewable energy verification systems and climate accounting methods should not be understood as a policy instrument in which a politically set incentive effect is already built into the methodology of data collection. Instead, they should be used as neutral information tools.

- **Assessment of climate impact on the basis of the GHG inventory**:
  Assessing the potential energy transition contributions of a company's energy procurement decisions can ultimately take place on the basis of the information contained in the GHG inventory (including accompanying information on quality characteristics of purchased energy). In addition to incentives set by customer demands and other stakeholders, policy instruments can also be used to incentivise certain forms of energy procurement.

- **Use of granular GOs**:
  Granular guarantees of origin (GOs) could help to come as physically close as possible to reflecting green electricity supply in the carbon footprint, thereby addressing a widespread concern. They can combine temporal and spatial production and consumption information, based on which the market-based and location-based approaches could be integrated in their respective targets. The accounting methodology in the market-based approach would have to be adapted accordingly.

1 INTRODUCTION

In standards and methods for corporate greenhouse gas (GHG) accounting, there are two different approaches to accounting for electricity procurement: the location-based and the market-based approach. In particular, accounting standards for product carbon footprints (PCF) often leave room for manoeuvre, which makes it possible to choose between the two approaches or to argue in favour of one or the other. Companies therefore often choose the approach that suits them best from their specific perspective. This is understandable from the company's view but can lead to the attributes of renewable energy production being counted and claimed multiple times. With far-reaching consequences: the non-harmonised and ambiguous application of accounting approaches harbours the risk of overestimating the environmental impact of renewable energy sources (RES) and leads to inconsistent results in GHG accounting. As a result, the entire logic and objectives of GHG accounting risk losing their credibility.

In addition, the two accounting approaches cannot always fulfil the expectations and requirements placed on them in practice. The following example illustrates the current problems.

An innovative, energy-intensive company would like to set up a production site in Schleswig-Holstein (SH), Germany – assuming that using renewable energy generated in SH in its industrial production can have a positive impact on its carbon footprint. The ongoing expansion of onshore and offshore wind energy in SH would therefore have a positive effect on the establishment of industry companies. In practice, however, this plan fails due to the current regulations on GHG accounting. Why?

- In order to allocate the renewable electricity volumes from SH using a **location-based approach**, the company would have to use the generation mix of the electricity in SH as a basis – orientated along the borders of the federal state. However, this leads to double counting of RES volumes if other companies refer to the overall German grid mix. Furthermore, regional grid boundaries cannot be clearly drawn.

- If the company were to pursue a **market-based approach**, it would have to use the guarantees of origin (GO) from the SH plants as the basis for GHG accounting. The problem here is that the majority of renewable energy generation in Germany is subsidised by the state, which means that no GOs can be issued for the renewable energy volumes under German energy law (ban on double marketing). Unsubsidised volumes from the region are unlikely to be sufficiently available to the energy-intensive company.

This means that the plan for low-emission production by locating at a renewable energy-intensive site cannot currently be credibly implemented in accounting practice.

However, the reliability and credibility of GHG accounting is increasingly becoming the focus of companies and public institutions. After all, a PCF in particular is now a strong currency in many contexts – with significant economic relevance for companies:

- The Corporate Sustainability Reporting Directive (CSRD)[1] obliges companies to provide information on their corporate carbon footprint (CCF).
- The product carbon footprint (PCF) is increasingly becoming a tendering criterion for companies and public clients.
- Frameworks such as the EU's Carbon Border Adjustment Mechanism (CBAM)[2] place the carbon footprint at the centre of a possible taxation or payment obligation.

In order to resolve this dilemma, it must be in the interests of both companies and policymakers to agree on uniform and clear standards for the accounting and reporting of green electricity. Depending on the objective, one or the other method may be more favourable. But which objective should be pursued? Which method would be most suitable in terms of consistent, fair and transparent GHG accounting?

This issue is the subject of controversial debate at many levels and also leads to a lively exchange of views in the context of leading carbon accounting standards such as the Greenhouse Gas Protocol. As part of its revision process, the effectiveness and appropriateness of the Scope 2 guidance and proposed accounting alternatives were discussed with over 1,000 stakeholders, resulting in a written consultation on the revision of the guidance (World Resources Institute 2023b).[3]

In the following, both approaches to electricity accounting are presented with regard to their advantages and disadvantages for GHG accounting. Problems associated with using both approaches in parallel are presented in more detail. Based on this, we give an overview of the scientific discussion of energy transition benefits of the accounting approaches and develop a proposal for dealing with the challenges described above.

[1] Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014 and Directives 2004/109/EC, 2006/43/EC and 2013/34/EU as regards corporate sustainability reporting.

[2] Regulation (EU) 2023/956 of the European Parliament and of the Council of 10 May 2023 establishing a carbon border adjustment mechanism.

[3] In the context of corporate reporting, emissions are allocated to different scopes. Scope 1: Direct emissions that arise directly from a company's production; Scope 2: Indirect emissions from purchased energy; and Scope 3: Indirect emissions that arise in the upstream and downstream supply chain.

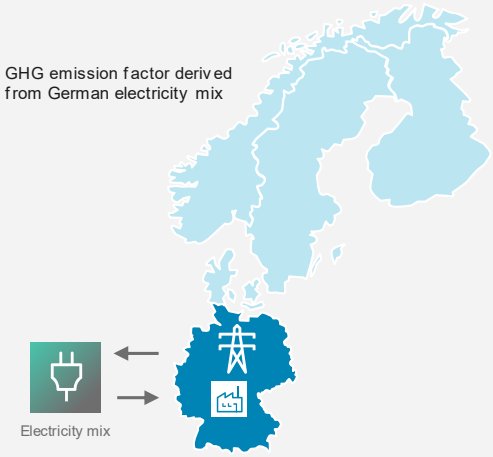
2 TWO APPROACHES TO ELECTRICITY ACCOUNTING: MARKET-BASED & LOCATION-BASED

Methodologically, two approaches can be distinguished for the greenhouse gas accounting of electricity procurement at company or product level.

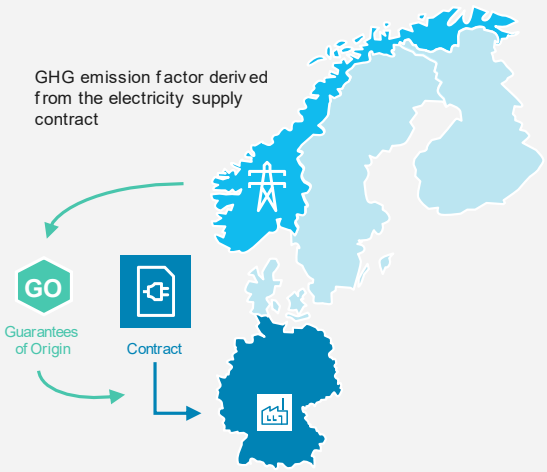
The location-based approach

If the GHG accounting follows a **location-based approach**, the basis for determining the emission factor of electricity is the mix from the energy sources that feed into the grid of the defined area.

Example: German electricity mix (electricity mix of the power plants feeding into the German grid area)



Example: Green electricity supply contract (with respective electricity disclosure, whereby the market area may cross borders and grid areas)



The market-based approach

If GHG accounting follows a **market-based approach**, contractual instruments such as electricity supply contracts serve as the basis for determining the emission factor to be used for GHG accounting.
As a rule, verification instruments such as energy attribute certificates document the electricity quality based on which the emission factor is calculated.

2.1 Criteria and requirements for market-based instruments

In order to use a contractual instrument (usually a supply contract for electricity, backed by energy attribute certificates) for a market-based approach to GHG accounting, defined criteria must be met. First and foremost, such a contractual instrument must exclude the double claiming and double marketing of the attributes of electricity quantities – especially in the case of energy from renewable sources. Quality criteria for market-based instruments are set out, for example, in the GHG Protocol Scope 2 Guidance (World Resource Institute and World Business Council for Sustainable Development 2015, p. 60) for accounting for purchased energy at company level or in ISO 14067 for calculating a PCF (ISO 14067:2018, p. 57).

According to the GHG Protocol Scope 2 Guidance, contractual instruments for the market-based accounting of electricity must fulfil the following criteria (World Resource Institute and World Business Council for Sustainable Development 2015, p. 60):

- They transmit the attributes of a unit of electricity produced, based on which the GHG emission rate is to be determined.
- They are the only contractual instrument that bears the attributes of a specific quantity of electricity. There must be no double marketing.
- They are tracked and cancelled for the appropriate purpose.
- They are created and cancelled as soon as possible.
- They originate in the same energy market as the electricity-consuming units of a reporting company.
- It is ensured that a residual mix is published in the context of the use of the contractual instrument, which reflects the GHG intensity of unclaimed or publicly shared electricity attributes.
- If supplier-specific emission factors are issued by means of contractual instruments, it must be ensured that these are calculated based on the energy supplied, and corresponding evidence must be obtained and validated on behalf of the customer.
- In the case of a direct connection to a generation plant, it must also be ensured in the context of the use of the contractual instrument that no contractual evidence is sold to third parties and that the attributes of the electricity generation are only marketed once.

Examples of contractual instruments include **electricity disclosure statements** for electricity supply, the **cancellation of Energy Attribute Certificates (EACs)** on behalf of electricity consumers and **power purchase agreements (PPAs).** The aforementioned instruments work together to exclude double marketing: EACs can only fulfil their task of allocating the characteristics of energy production to energy consumers and thereby excluding double marketing in conjunction with a disclosure obligation. Conversely, a disclosure system must be backed by an instrument for the clear allocation of green attributes, such as EACs. PPAs are not primarily a verification instrument, but a form of contract design for the mostly longer-term purchase of electricity volumes, whereby green attributes of the corresponding electricity volumes are usually also transferred to contractual partners. However, if an EAC system exists in the market region, proof via EAC transfer or cancellation on behalf of the contractual partner is also necessary here in order to exclude multiple consideration of green attributes.

To complete the logic of a disclosure system, it is necessary to calculate **the residual mix**. This represents the characteristics of all energy quantities whose attributes were not tracked and were therefore not allocated to any specific purchasers (e.g. through EAC cancellation). Consequently, this is the generation mix of a country that has been adjusted for the quantities of renewable energy that have been tracked and utilised elsewhere.

The **European Guarantees of Origin system** in accordance with Art. 19 RED II (Renewable Energy Directive 2018/2001 amended by Directive 2023/2413)[4] fulfils the GHG Protocol criteria in conjunction with the electricity disclosure obligation under the Electricity Market Directive (Art. 18 Para. 6 in conjunction with Annex I No. 5 Directive (EU) 2019/944)[5] . This means that a market-based accounting approach in accordance with current standards can be applied in the European electricity market without further ado. The required residual mix calculations can be found on the website of the Association of Issuing Bodies (Association of Issuing Bodies 2024).

Other examples of EAC Systems are **RECS** in the USA, Canada and Australia. The **I-REC(E) Product Code of the International Tracking Standard Foundation (I-TRACK)** on EAC systems for electricity is also committed to the usual quality criteria for a market-based instrument. However, it must be ensured that the practical implementation at the respective market location is also checked accordingly with regard to the I-REC(E) standard, for example, and that double marketing of energy properties can also be prevented in this context. This applies in particular if there is no national regulation on energy disclosure. Other national EAC systems are currently being set up in China and South-East Asia (Jati 2023; Jati et al. 2023).

2.2 Criteria and requirements for the location-based approach

Compared to the market-based approach, criteria for location-based accounting are defined less precisely. Common standards such as the GHG Protocol or the standards ISO 14064 and ISO 14067 indicate that the **average emissions from energy production in a defined grid area** should be used as the basis for determining a location-based emission factor. Suitable spatial boundaries of such a grid area should correspond to the region of energy distribution and utilisation. These can be grid balancing areas, for example. All emissions generated during energy production should be taken into account, as well as all physical net energy imports/exports and the associated emissions. It can be assumed that this also includes grid losses (vgl. World Resource Institute and World Business Council for Sustainable Development 2015; ISO 14064-1:2018; ISO 14067:2018).

Due to these rather vague regulations, the grid area to be selected can be defined in very different ways and orientated towards administrative boundaries, such as municipal or urban areas, districts, federal states or national borders. A definition along certain grid zones is also conceivable, which can be delimited by different grid operators, for example, or orientated towards market areas or electricity price zones.

This diversity already highlights a major disadvantage of the location-based approach: **the boundaries can be drawn arbitrarily.** In the general understanding which has emerged from the application of the accounting standards, the emission factors should be calculated on the basis of the grid area of a state. However, this is not binding. In Germany, the federal states, for example,

[4] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast), amended by Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652.

[5] Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market in electricity and amending Directive 2012/27/EU (recast).

determine emission factors for their state borders. If the emission factor of the federal state is used in some cases and the national emission factor in others, this results in double counting of RES attributes.

For Germany, the German Environment Agency publishes annual values for the emission factor of the German electricity grid based on the German Emissions Inventory (Umweltbundesamt 2024b). At the same time, institutions and initiatives are increasingly publishing emissions data at regional level, e.g. for the federal states, or data with a higher level of temporal granularity (daily or hourly emissions data) (Doms 2023; FfE 2023). This can incentivise the use of more granular data in GHG inventories if they show lower emissions than the national mix.

2.3 Comparative characteristics of the two approaches to current balancing

The following table compares the characteristics of the two approaches. It becomes clear **how the advantages and disadvantages** can affect **GHG accounting depending on the objective**.

	Location-based approach	Market-based approach
Assessment basis	Emission factor is calculated based on the average production mix of the grid's power plant fleet.	Emission factor is calculated based on contractual instruments (e.g. electricity supply contract or other proof) between supplier and consumer, in which the origin of the electricity is documented via a verification system, e.g. EACs in conjunction with electricity disclosure.
Market location	Applicable in all electricity markets, as accounting is based on the grid or geographical area, although the region size or definition of the grid area may vary.	Only applicable in markets with an adequate RES verification system that meets the criteria for market-based instruments. Accounting logic corresponds to the structures of liberalised electricity markets.
Approaching physical realities	Only approximates physical conditions in small grid areas. With a nationally defined grid, the physical reference depends on the interconnection with other countries. However, the boundaries of the electricity grids are generally too large to establish an actual causal connection or physical proximity between generation and consumption.	The physical reality is deliberately separated from the commercial processing (trading) of the electricity and its attributes.
Cross-border energy flows	Should be recognised in the emission inventory, as emission factors should generally reflect electricity consumption in a defined geographical region. However, also national emission factors based on the electricity production of a country can be used (World Resources Institute 2015, p. 47).	Can be documented between two or more countries, provided they participate in a standardised verification system.
Proof and sources	Grid-related emission factors from suitable data sources (e.g.	Emission factors must be determined from the electricity mix of the traded

	emission factor of the German generation mix published by the German Environment Agency (2024a))	electricity. This requires, for example, trader information, the electricity disclosure of an electricity product, EAC or PPA with EAC. These instruments must fulfil the quality criteria for the market-based approach.
Influencing companies to decarbonise their own electricity procurement	No influence possible Decarbonisation of electricity procurement only possible through appropriate choice of location (in grid areas with low emission factor) and energy efficiency measures, as well as switching from grid procurement to self-supply systems on the company premises with direct connection	Influence possible through targeted procurement of green electricity Honours consumer/procurement decision Adaptability to current market developments (e.g. granular reporting via EACs, enabling of PPAs)
Influence of consumers on the expansion of renewable energies	No influence when electricity is purchased from the grid	Influence is possible if expansion is incentivised by demand for green electricity. This can vary depending on the subsidy regime, but the incentive to expand via PPAs only exists if customers can acquire associated green attributes. Power quality verifiable in terms of additionality via information on EACs.
Double counting risk when using one approach (vgl. Holzapfel et al. 2023; Holzapfel et al. 2024)	There is a double counting risk if different temporal and geographical demarcations can be used so that, for example, different companies use different grid demarcations for the respective accounting period.	If the market-based approach is applied consistently, the double counting risk can be minimised. Risks nevertheless remain, as ○ Residual mix publication is not given everywhere and ○ LCA databases are based on location-based approaches.

Table 1: Characteristics of the market-based and the location-based accounting approach (based on Mundt et al. (2019), Sakhel et al. (2022a), Kemper et al. (2024)).

The characteristics of the two approaches are not always comparable and, depending on the objective, one or the other approach may appear to be the more favourable method. Against this backdrop, there has long been a lively debate among experts, particularly about which of the two approaches comes closest to the physical reality of the electricity mix on the one hand and is most beneficial to the energy transition on the other. The answer in short: it depends.

In view of the objective of achieving harmonised, comparable and credible GHG accounting, both approaches appear to have advantages and disadvantages:

The argument in favour of using the location-based approach is that it more closely reflects the physical reality between generation and consumption compared to market-based approaches. However, the fact that the definition of grid or geographical boundaries appears arbitrary due to the lack of concrete specifications must be viewed critically. Furthermore, grid areas are usually technically connected to each other across wide regions. In this respect, it is only possible to draw a boundary to a manageable region virtually in any case. In addition, the larger a region is for the location-based approach, the further away it is from the physical realities. Moreover, cross-border energy flows are only reflected to a limited degree. In Germany, an electricity customer in Bavaria is more likely to receive electricity from Austria than from northern Germany, and a customer in Flensburg is more likely to receive electricity from Denmark.

A market-based approach is seen as advantageous in the context of corporate carbon accounting insofar as companies' procurement decisions have an impact on their carbon footprint. The tradability of EACs creates the possibility of directing payment flows in favour of renewable energies. The question of whether this actually leads to an additional expansion of RES will be discussed further below. However, a structural benefit for the energy transition can be attributed to the market-based approach, as EACs can be used, for example, to enable the transfer of green attributes in the context of a PPA.

However, the market-based approach allows for a complete decoupling of energy and attribute transfers, without regard to the representation of physical realities. This leads to a very abstract representation of the origin of electricity, according to which green electricity can be supplied from many thousands of kilometres away. Tradability also makes it possible for actors who are themselves located in a grid region whose location-based mix is significantly worse to capture the green attributes, independent of infrastructural constraints and other physical realities.

3 WHY THE PARALLEL APPLICATION OF TWO APPROACHES TO ELECTRICITY ACCOUNTING IS PROBLEMATIC

Due to the aforementioned characteristics of the two accounting approaches, the **selection and application in practice – depending on the objective of the emissions assessment –** is **case- and context-specific**. For example, the location-based approach is suitable for life cycle assessments (LCA) with the aim of comparing two variants of, for example, production processes, as average data is more suitable for the general comparison of two alternatives. A location-based approach also makes sense in the context of national or municipal targets relating to the decarbonisation of the energy system, as the development of generation capacities is considered at a territorial level here.

A market-based approach, on the other hand, is suitable if the accounting methodology is intended to represent GHG emissions – e.g. in a financial year – at company (CCF) or product (PCF) level. The market-based approach can act as a lever, particularly for the goal of lower-GHG production, as it enables the mapping of active procurement decisions. In the location-based approach, the company would have little room for manoeuvre in terms of decarbonising electricity procurement. However, a prerequisite for a market-based approach is that it is applied on the basis of a valid verification system, comparable to the European system of guarantees of origin, for example.

> Conventional standards for climate accounting do not provide clarity here, but instead handle **requirements and recommendations very differently**. Most include both approaches and leave room for interpretation.

Some recommendations favour the market-based approach, but do not exclude the location-based approach, such as ISO 14067 for the calculation of product carbon footprints (PCF) (ISO 14067:2018). According to the GHG Protocol Scope 2 Guidance for reporting at company level, companies are obliged to report both methods (World Resource Institute and World Business Council for Sustainable Development 2015).

The ISO standards even contradict themselves with regard to company and product level. For example, ISO 14064 requires a location-based approach to GHG accounting at the organisational level, while ISO 14067 favours a market-based approach to GHG accounting for products (vgl. ISO 14064-1:2018; ISO 14067:2018). **EU regulations** are also **inconsistent** with regard to the accounting of GHG emissions from electricity purchases: the ESRS E1 standard, according to which GHG accounting must be carried out as part of the Corporate Sustainability Reporting Directive (CSRD)[6] , requires both approaches in dual reporting. This means that both emission factors must be reported, but this still means that downstream accounting only processes one of the values. In contrast, the EU Product Environmental Footprint (PEF),

[6] Directive (EU) 2022/2464 of the European Parliament and of the Council of 14 December 2022 amending Regulation (EU) No 537/2014 and Directives 2004/109/EC, 2006/43/EC and 2013/34/EU as regards corporate sustainability reporting.

the method recommended by the EU in Recommendation (EU) 2021/2279[7] for recording the environmental factors of products, is clearly in favour of the market-based approach (Europäische Kommission 2021). This is also followed by the proposal for accounting for GHG emissions from batteries by the Joint Research Centre of the European Commission (Andreasi Bassi et al. 2023). In contrast, the draft delegated regulation on GHG accounting of batteries in the context of the Battery Regulation (EU) 2023/1542 stipulates a location-based accounting approach – contradicting the PEF methodology (European Commission 2024).

> In practice, the choice of accounting approach is therefore often based on what is considered more favourable in terms of the resulting GHG emissions depending on the company's situation.

If, for example, a location already has a high proportion of renewable energy in the public electricity grid, the company will probably prefer the location-based approach and benefit from the advanced decarbonisation of the energy supply in the country in question. If, on the other hand, it is located at a site with a higher emission factor in the grid, a market-based approach in the form of purchasing 100% electricity from renewable sources would lead to an emission factor of 0 (unless Scope 3 emissions for the renewable electricity were included voluntarily).

The use of this freedom within the accounting standards means that both approaches can be found in practice and no stringent line for decision-making is recognisable.

As a result, the parallel application of the market-based and location-based approach leads to double counting of green electricity volumes. In Illustration 1 this is illustrated using the example of Norway[8] .

[7] Commission Recommendation (EU) 2021/2279 of 15 December 2021 on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations.

[8] The Norwegian Water Resources and Energy Directorate (NVE) reports the residual mix for Norway and sets clear guidelines on which electricity mix energy suppliers that do not purchase EACs may use for publication (Seebach 2023; Norwegian Water Resources and Energy Directorate 2024, https://www.nve.no/energy-supply/electricity-disclosure/). However, not all companies use this value in their carbon footprint.

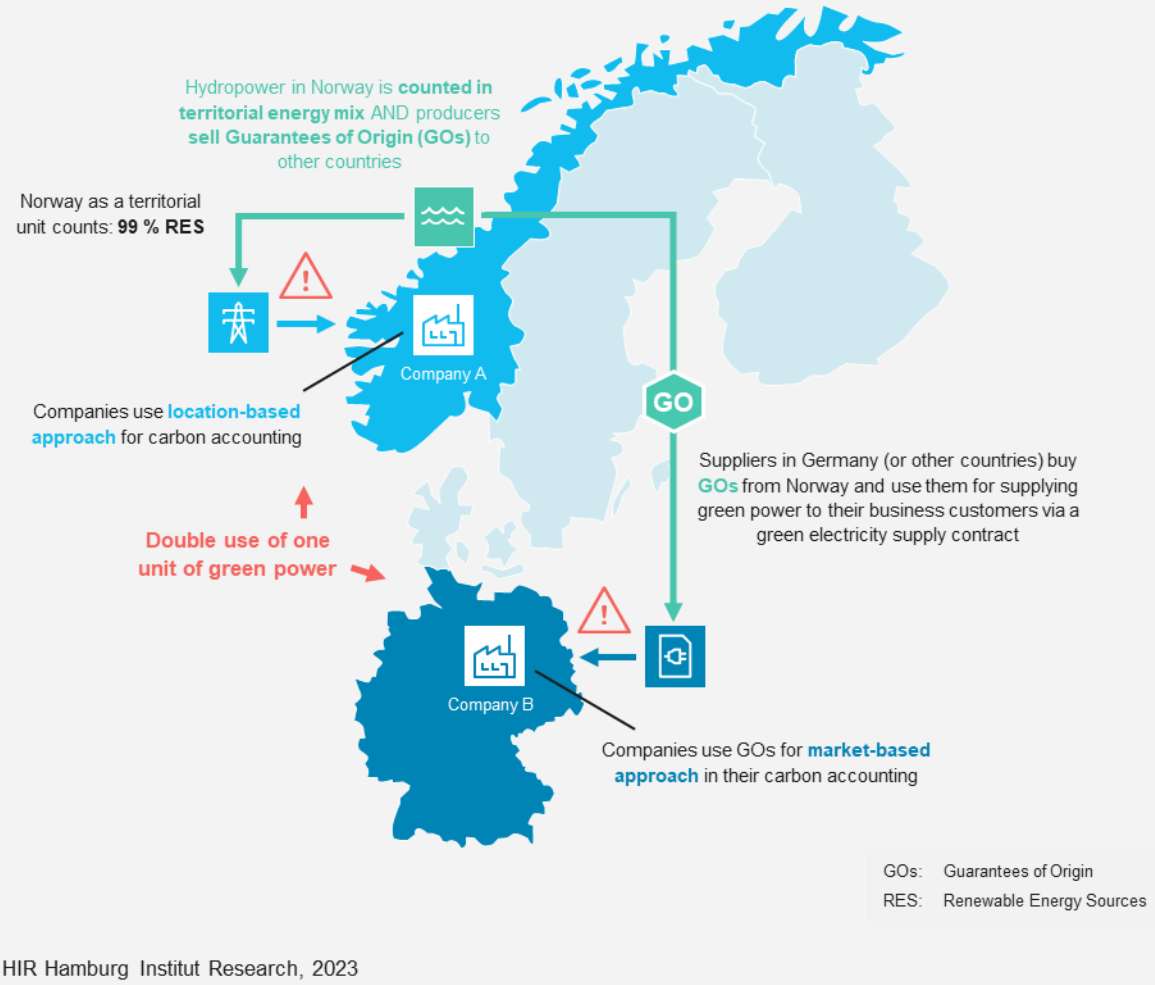


Illustration 1: Parallel use of the two accounting approaches leads to double counting

The example of Norway

The double counting of green electricity volumes has recently been the subject of critical reporting in some specialised media. This mostly centred on the electricity grids in Iceland and Norway(Böck 2022, 2023, 2024; Herrmann et al. 2023).

Due to the favourable conditions for energy production from renewable energy sources - especially hydropower – the share of renewable energies in the electricity generation mix in Norway is almost 100 %. This means that Norway's national electricity grid is almost entirely supplied by renewable energy (Norwegian Water Resources and Energy Directorate 2024).

Using the location-based approach, companies based in Norway (company A in Illustration 1) that purchase electricity from the grid can report almost 100 per cent green electricity procurement in their GHG emission inventory. At the same time, Norway is part of the European Guarantee of Origin (GO) system, within which GOs are issued for electricity production from RES. In line with the book & claim principle, the physical flow of electricity is separated from its attributes, which in turn can be traded independently.

The book & claim principle

The issuing, transfer and cancellation of guarantees of origin are based on the book & claim principle. The physical energy flow and the attributes of the energy are separated and decoupled from each other.

Book: A generation plant A produces renewable energy. A guarantee of origin is issued for each MWh of energy produced, which bears the attributes of the energy generated. However, the actual amount of energy is marketed as "grey" energy.

Claim: The renewable attributes of the energy generated can now be tracked and allocated using the guarantees of origin issued. For example, consumers can purchase energy from the local mix. The energy supplier cancels GOs from generation plant A corresponding to the amount of energy purchased from the local mix. In this way, the energy purchased – regardless of the actual local electricity mix – can be disclosed as renewable energy, e.g. 100% solar power.

A large number of these GOs are sold to energy supply companies in Germany, which can then sell green electricity contracts to their customers using Norwegian hydropower GOs, for example. In this way, fossil electricity attributes from Germany are exchanged for green attributes from Norway. Conversely, the Norwegian electricity mix as shown in the national electricity disclosure deteriorates and thus has a significantly higher fossil share due to the swapped fossil attributes (as shown in Illustration 2) than would correspond to the electricity mix in the grid.

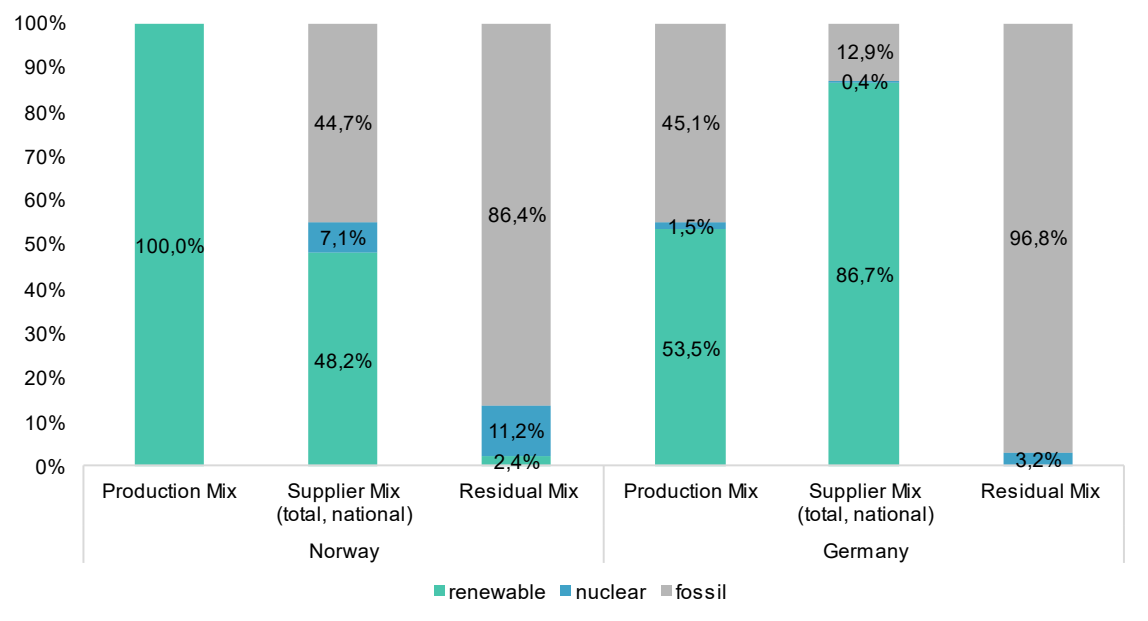


Illustration 2: Generation mix, total supplier mix and residual mix in the electricity sector: the examples of Norway and Germany in 2023 (shares of various energy sources in per cent)

Note: The generation mix corresponds to the total annual supply of energy attributes generated in a country (based on electricity generation statistics). The supplier mix includes both explicitly tracked attributes (energy quantities for which GOs have been cancelled and, in Germany, subsidised electricity production quantities) and electricity quantities that are not explicitly tracked (if non-tracked commercial offers are reported on, the residual mix can be used). (Individual) supplier mixes are shown in electricity disclosure statements.
The national residual mix is calculated by adjusting the generation mix of the respective country for the attributes of explicitly tracked energy quantities (i.e. energy quantities for which GOs have been cancelled and, in Germany, also for subsidised electricity production quantities). Cross-border trading of electricity and GOs means that countries can have surpluses or deficits in attributes. Attribute surpluses are included in the "European Attribute Mix", which is used by countries with attribute deficits to "top up" the national residual mix.

Source: Own illustration, based on Association of Issuing Bodies (AIB) (2024).

Companies in Germany that have concluded a green electricity supply contract for which the respective energy supply company has purchased GOs from Norwegian hydropower (Company B in Illustration 1) will use the market-based approach to account for the green electricity accordingly.

> As a result, both company A and company B have counted the same amount of green electricity production in their GHG emission inventory – once using the location-based and once using the market-based accounting approach. In this way, both companies can present themselves as climate-friendly in the emission inventory, even though this is based on the same amount of green electricity that was only generated once.

This double counting of RES quantities means that

- GHG emission inventories can vary greatly depending on the calculation method and thus make it harder or even impossible to compare companies and products due to the parallel use of two accounting approaches.
- the environmental impact of RES volumes is overestimated and

- market-based mechanisms in particular are losing credibility.

To avoid double counting and improve the comparability of CCFs and PCFs, only one accounting approach should be used consistently across the entire accounting chain (vgl. auch Holzapfel et al. 2023).

Important aspects when assessing which approach should be favoured for corporate carbon accounting are a) ensuring transparent and reliable GHG accounting and b) applicability in practice.

4 CURRENT DISCUSSION ON THE ENERGY TRANSITION BENEFITS OF THE TWO APPROACHES

When considering the advantages and disadvantages of the two accounting approaches, their respective **energy transition benefits** feature heavily in the discussion.

The energy transition benefits of the market-based approach are discussed in more detail and more critically in expert circles than the location-based approach. The reason for this is that Scope 2 emissions make up a large proportion of total GHG emissions for many companies and the market-based approach enables them to reduce these completely through a purchasing decision. With regard to the discussions on the energy transition benefits of the **market-based approach**, it is important to differentiate between two issues:

- Does the respective approach offer a financing effect to renewable energy producers and can it therefore represent a benefit in terms of accelerating the energy transition?
- Can the accounting methodology in the carbon footprint show whether a company is acting in a manner which is beneficial to the energy transition?

The main features of the discussion are presented below. We then review current proposals for adapting the accounting methodology of the market-based approach. Based on this overview, we develop our proposed solution in chapter 5.

4.1 The accounting approach as a driver for the energy transition

The location-based approach could be seen as beneficial for the energy transition in view of its influence on companies' choice of location.

The interdependencies could be as follows: If companies had to account for their energy procurement based on location, only locations with high RES generation would be attractive for them in order to reduce their GHG emissions. The choice of location would depend on the nature of local electricity production and become an important decision-making factor for the establishment of companies, as in the example in Section 1.

Conversely, this means that governments would have to expand RES in order for their states or regions to remain attractive as a production location and avoid the migration of energy-intensive industry. The application of the location-based approach could therefore lead to the expansion of RES being incentivised by the state.

At the same time, the location-based approach can help to ensure that the majority of companies are in favour of the expansion of renewable energies in their region. This could strengthen the acceptance of RES in the respective region (Ecohz 2024). However, there is no incentive to contribute to the financing of new renewable energy installations, as companies cannot count these towards their carbon footprint. RES expansion supported by individual companies, for example via PPAs, only has a minor impact on the average emission factor of the overall grid.

In effect, there is no mechanism in the location-based approach that would allow for an increase in green electricity demand to have an effect on supply.

There are no comprehensive scientific studies on the extent to which the location-based approach has created additional energy transition benefits and contributed to RES expansion. If the location-based approach would be the singular approach for GHG accounting, the expansion of renewable energies would be primarily driven by political decisions and support measures (unless electricity from RES is cost competitive independent of its “green” characteristics). The location-based approach does not establish a market-based link between demand and supply of electricity from RES but leaves the responsibility for the implementation of the energy transition primarily to state actors.

With regard to the market-based approach, the following hypothesis is put forward: The additional income generated for RES plant operators through EAC sales means that more can be invested in the energy transition. However, scientific findings do not support this hypothesis. Rather, it is unlikely that the market-based approach or EACs have contributed to increasing RES production to date (Brander et al. 2018). The financing effect on RES expansion was analysed by Hamburger and Harangozó (2018) empirically for the first time. They found that, at the time of the study, the demand for renewable energy, which can only be met by green electricity with GOs, had no impact on the development of renewables in the EU, Norway, Iceland and Switzerland. Galzi (2023) also comes to the conclusion with regard to a possible incentive effect in France that most green electricity customers have not contributed to RES expansion.

Nevertheless, an increase in demand for green electricity could lead to financing effects taking effect after all (Brander et al. 2018), as the studies related to periods of low EAC prices and consequently modest revenues from the sale of EACs. It can be observed in the European market that prices for GOs fluctuate and have recently risen (Wimmers and Madlener 2024). There are also national differences between green electricity markets: for instance, Dutch GOs from wind farms have achieved prices of €1.5 – 2 above the EU price in 2021 – 2022 (Kerkhof 2022).

The potential of EACs for supporting RES expansion might therefore still exist. In addition to the small amount of additional revenue that can be generated to date, a major challenge lies in the volatility of EAC prices and therefore the difficulty of planning. The ratio of EAC revenues to electricity revenues must be considered here: in the European market, electricity prices were also very high during the GO "high price period" with several €/MWh (see also Styles et al. 2023a).

Particular attention should be paid to the role of EACs in non-subsidised plants that rely on as many revenue streams as possible. Should EAC prices establish themselves more consistently at

a comparatively high level in the future, this could influence investment decisions as part of the overall revenue concept. This applies in particular if a high-price segment were to become established for plants with certain quality characteristics (e.g. unsubsidised new plants or electricity volumes from a certain technology, such as agrivoltaics).

It should also be borne in mind that the expansion of renewable energy in the EU has so far been primarily subsidy-driven. The market value of EACs, which are also issued for subsidised plants in most member states, must be taken into account in state support in accordance with Art. 19 RED II and thus primarily have the effect of reducing subsidy costs. The marketing of green attributes as part of the overall marketing concept could become increasingly important for the future market-driven expansion of RES. Power Purchase Agreements (PPAs) play a special role here. They are crucial for operators of purely market-financed plants to reduce risk, as they generate long-term predictable revenue streams – unlike income from the sale of electricity on the electricity exchange and the separate marketing of EACs. Revenue risks are also reflected in credit conditions, meaning that PPAs often become a prerequisite for the realisation of renewable energy plants without state subsidies. Accordingly, PPAs play an important role in the EU's electricity market reform in order to realise both price stability for companies as electricity consumers and RES expansion targets.[9] For companies, PPAs also offer the opportunity to credit the purchase of renewable energy to their carbon footprint. EACs are an important component in the implementation of PPAs in order to be able to transfer and exclude double marketing of green attributes. In contrast to the procurement of EACs traded separately to energy volumes, PPAs also give companies planning security for purchasing renewable energy with certain characteristics (e.g. from unsubsidised plants below a certain age), which may not be reliably available on the "free" EAC market.

EACs also provide information on renewable energy installations in suppliers' own electricity generation portfolios. If suppliers pass on the corresponding green attributes to their own customers, these EACs are also not freely traded.

From an overall perspective, EACs are an important tool for consumers – on the one hand to exclude double marketing and on the other to compare the quality of green electricity products based on the information on the electricity's origin recorded on EACs. Labels that certify green electricity products with actual benefits for the energy transition, for example, can provide support here. Additionality criteria play an important role here, such as the question of whether electricity comes from unsubsidised new or repowered plants (see below). This gives consumers the opportunity to specifically request green electricity products with added value for the energy transition or to conclude a contract with suppliers who actively invest in the expansion of renewable energy and thus promote the energy transition (vgl. Styles et al. 2021).

4.2 Does the GHG emission inventory reflect the energy transition benefits of companies' energy purchasing decisions?

In the case of GHG accounting using the location-based approach, emission reductions in companies' emission inventories are due to the fact that the decarbonisation of the grid has progressed as

[9] See Articles 19a and 19b of Regulation (EU) 2024/1747 of the European Parliament and of the Council of 13 June 2024 amending Regulations (EU) 2019/942 and (EU) 2019/943 as regards improving the Union's electricity market design.

a result of the expansion of renewable energy. It is argued that the location-based approach makes actual emission reductions in the energy supply visible. However, this effect is not incentivised by companies' GHG accounting.

Furthermore, there are no incentives for companies as electricity consumers to actively support the energy transition by purchasing electricity via grids. Even a PPA with an unsubsidised new plant, which has enabled its realisation, could not be taken into account in the carbon footprint with the location-based approach, as it would only marginally influence the general electricity mix of the grid. Accordingly, if the accounting methodology focussed on the location-based approach, there is a risk that (corporate) electricity consumers would be released from their shared responsibility for the energy transition. One exception is the realisation of self-supply systems within the company boundaries (with a direct connection to the company, i.e. without using the public grid). This directly reduces the purchase of electricity and therefore the emissions recognised in Scope 2. However, in such a scenario, the decarbonisation of electricity grids would be driven exclusively by stimuli on the generation side, in particular through politically set incentives, until RES become fully competitive. If electricity is purchased from the grid, companies could only influence the Scope 2 emissions of purchased energy through their choice of location.

However, when using the market-based approach and improving the emission inventory with the use of contractual instruments reflecting electricity procurement, it is criticised that this does not immediately have an impact on the energy transition, as new renewable energy plants have not necessarily been built (Brander et al. 2018; Bjørn et al. 2022a, 2022b). Instead, there may be a redistribution of renewable energy attributes from plants that would have been or were realised even without EACs (e.g. green attributes from old hydropower plants). This is criticised as a misallocation of climate change mitigation efforts, which leads to supposed emission reduction successes being overestimated instead of real emission savings (Brander et al. 2018; Bjørn et al. 2022a, 2022b).

In order to be able to identify electricity volumes in the market-based approach that generate an actual benefit for the energy transition, various institutions define so-called additionality criteria, e.g. UBA, WWF or RE100 (RE100 2022; World Wide Fund for Nature 2021; Umweltbundesamt 2017). These relate, for example, to the age of the plant or the subsidy status, exclude certain generation technologies and set geographical limits. Labels such as ok-power, Grüner Strom Label or EKOenergy ecolabel stand for certified electricity volumes that fulfil defined additionality criteria (Energievision e.V. 2024; Grüner Strom Label e.V. 2022; EKOenergy ecolabel 2024). **Additionality criteria** can be used to differentiate between different qualities of green electricity –green electricity that fulfils certain additionality criteria is said to have an energy transition benefit.

4.3 Current proposals to adjust the accounting methodology of the market-based approach

In order to counteract the criticism that the emission inventory of a company that reports emissions from electricity procurement according to the market-based approach does not allow any reliable statements to be made with regard to actual emission reductions and energy transition benefits, approaches for adapting the market-based accounting methodology have been proposed in the literature. Alternatively, it is suggested that the location-based approach be chosen. However, the

latter would result in companies no longer being incentivised to invest in the energy transition, e.g. through the procurement of green electricity with additionality criteria or PPAs (Bjørn et al. 2022b).

Alternative proposals stipulate that only renewable energy volumes that fulfil certain additionality criteria or are provided as part of a PPA may be counted towards the market-based approach (Bjørn et al. 2022b; Brander and Bjørn 2023; Seebach 2023). This discussion has also found its way into the current **review process of the Scope 2 Guidance of the GHG Protocol** (World Resources Institute 2023b) .

In the case of such a "qualified" market-based approach, it should be borne in mind that the residual mix, rather than the location-based approach, should then be used for the purchased electricity volumes that cannot be accounted for on the basis of contractual instruments. Otherwise, double counting problems would arise again.

The residual mix can also contain renewable attributes – namely those that are not explicitly tracked, as well as the attributes of EACs that are not cancelled due to a lack of demand, but expire. It can be assumed that company demand for conventional green electricity contracts would fall and corresponding EACs would expire, as these could no longer be counted in emission inventories due to their limited usability in the market-based approach. Economically rational companies would either invest in green electricity contracts that meet higher additionality criteria or switch to conventional electricity products with a higher share of fossil fuels. In Europe, companies are an important driver for the demand for green electricity (Ecohz 2021; Greenfact 2023), so it cannot be assumed that a fall in corporate demand for conventional green electricity products can be compensated for by an increase in demand from private customers.

If requirements within a qualified market-based approach mean that EACs that do not qualify for this increasingly expire, these "non-additional" renewable attributes could be used by companies without any form of green electricity procurement via the use of the residual mix in emission inventories. However, this would not make GHG accounting more conducive to the energy transition and EACs would no longer be able to fulfil their core task of clearly allocating renewable attributes to consumers.

Furthermore, the definition of additionality is quite challenging. For example, in addition to new, unsubsidised plants, a PPA with an old plant that is no longer subsidised could also have a climate benefit if this plant could not survive on the market without secured revenue streams and would otherwise be shut down before the end of its technical lifetime. Even the purchase of EACs from subsidised existing plants could have an indirect additionality effect if this reduces subsidy costs and thus makes more state funds available for the promotion of the energy transition elsewhere (see also Styles et al. 2021). Countries such as France, Italy and Portugal, for example, have switched to auctioning EACs from subsidised plants, with auction revenues directly benefiting the state budget (cf. Sakhel et al. 2022b).

> **It would therefore be advisable to build on the existing market-based approach** and thus create a solid basis for emissions accounting. The assessment of what is to be understood as green electricity that promotes the energy transition should take place outside of the GHG accounting methodology. The methodology for creating emission inventories **should not serve as a policy instrument**, but should create the basis for qualitative assessments.

EACs should have the function of a reliable verification instrument for the origin and attributes of electricity, and energy in general. How these are to be assessed and how, for example, incentives can be set by means of regulation and industry subsidy systems which influence energy procurement decisions must be defined elsewhere. In order for well-founded decisions to be derived from GHG emission inventories, **information on the additionality of electricity procurement** should have to be **provided as an obligatory accompaniment.**

5 PROPOSED SOLUTION: CONSISTENT USE OF THE MARKET-BASED ACCOUNTING APPROACH IN THE EUROPEAN ELECTRICITY MARKET

How can the double counting of RES attributes be reduced or prevented, in order to counteract the overestimation of progress with regard to the decarbonisation of companies' electricity supply? And how can clarity of application, comparability and a level playing field be established? The answers lie in harmonisation towards the consistent use of one accounting approach with clear rules.

> There is much to be said for favouring the **consistent use of the market-based approach**. This is because it offers the possibility of standardised accounting that is transparent and traceable – provided the quality criteria for market-based instruments are met.

Established GO system in place
A **transparent and robust verification system has been established** in the EU in the form of the GO system with its regulated registries (mostly national in scope), which are linked via the Association of Issuing Bodies (AIB). This has the potential to fulfil a verification function in a wide variety of contexts.

Decarbonisation of the electricity supply
Whether market, competition or regulatory requirements such as the CSRD Directive or the EU Taxonomy[10] : companies are under high pressure from several sides to set ambitious climate targets that are ahead of national GHG emission reduction targets. 8 % of the corporate reduction targets published by SBTi provide for the complete decarbonisation of electricity procurement by 2030 at the latest (see Science Based Targets Initiative 2024).

> With the market-based approach, companies can **clearly reflect their procurement decisions in the emission inventory** and thus demonstrate their decarbonisation efforts. **This can incentivise companies to invest in the energy transition themselves, e.g. via PPAs or by procuring green electricity with additionality criteria** (Bjørn et al. 2022b). As demand increases, supply must also be expanded over time.

With the location-based approach, on the other hand, complete decarbonisation of electricity procurement would only be possible once the grids have also been completely decarbonised. In

[10] Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment and amending Regulation (EU) 2019/2088.

addition to energy-saving measures, companies would therefore only have the option of relocating or switching from purchasing electricity from the grid to decentralised, off-grid renewable energy production for their own supply.

Relocation can lead to the migration of industry to particularly green locations; however, the decarbonisation of grids that are currently still dominated by fossil fuels is also urgently needed for climate change mitigation. Moreover, capital spent on relocation efforts would be lacking for the switch to greener production systems beyond the decarbonisation of electricity procurement.

Decentralised self-supply systems make a more direct contribution to the expansion of renewable energy generation than the purchase of a green electricity product (where the aggregated demand of all green electricity customers ultimately influences the expansion of renewable energy – unless in the case of large industrial customers who can directly trigger plant investments with high demand, for example via PPAs). However, switching to self-supply is not necessarily the most cost-effective option compared to purchasing renewable electricity from the grid. In the latter case, economies of scale can be utilised, e.g. the construction of wind farms at favourable locations for general supply vs. investments in individual plants with direct lines on company premises.

Driving forward the decarbonisation of the industry's electricity supply primarily through self-supply systems would increase the costs of decarbonisation (where feasible at all), meaning that the funds for further climate protection efforts would be reduced. In addition, the loss of industrial demand may reduce the likelihood of realising renewable energy projects that feed into the grid. Co-benefits for other electricity customers that could be supplied from these plants would no longer apply.

> The decision between purchasing electricity from the grid and self-supply should be driven by economic efficiency, not by GHG accounting rules. Focussing on location selection and self-supply would make decarbonisation more difficult for companies (even if green electricity procurement does not always go hand in hand with a GHG reduction).

Currently no specifications for grid boundaries

Another argument against the location-based approach is that there is currently still a risk of double counting due to different boundary setting in terms of time and geography. Green locations can be freely defined by companies. For example, as explained in the initial example, companies could draw regional grid boundaries – e.g. Schleswig-Holstein – but this would contribute to the double counting of RES volumes. This could be resolved by harmonising grid boundaries and time periods for accounting, but this is not currently the case in accounting practice. Such a process would still have to be initiated and then taken up by a suitable body.

Sector initiatives that want to promote the harmonisation of accounting methods in the relevant sector also tend to favour the market-based approach, e.g. TfS or Catena X (Together for Sustainability 2022, p. 48; Catena-X Automotive Network e.V. 2023, p. 22).

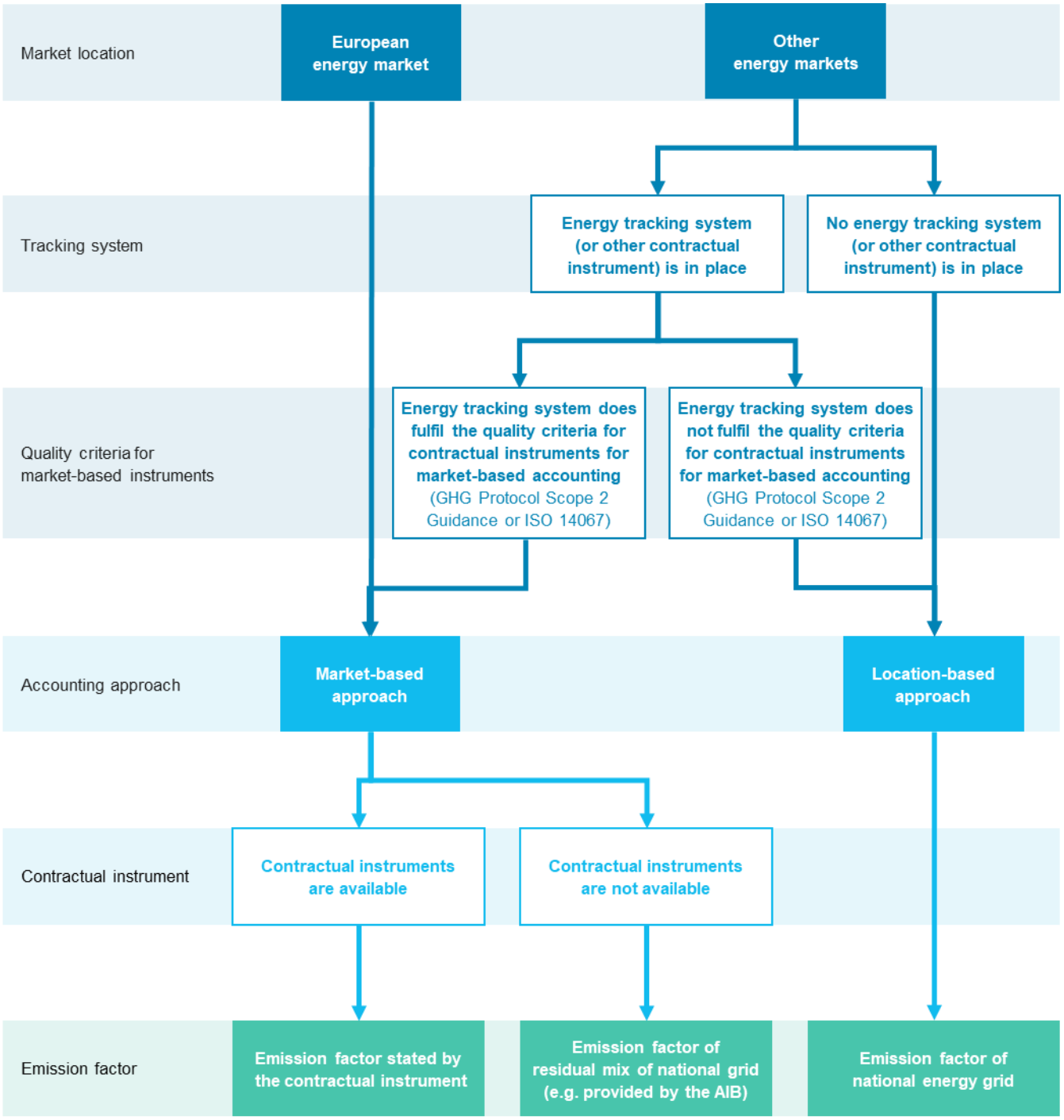
The qualitative assessment of companies' energy procurement decision should take place in other contexts, e.g. be laid down in industry subsidy conditions or in regulations. An assessment by customers and other market players (e.g. financing institutions) and stakeholders (e.g. NGOs) is also possible and useful in order to work towards green electricity procurement with particularly high energy transition benefits. Companies could emphasise their commitment in this regard, for example through certification (or the purchase of certified green electricity) or membership in initiatives such as RE100, which specify quality criteria for the purchase of electricity. These requirements could be verified using EACs, as these make the characteristics of each renewable

electricity quantity trackable (e.g. in terms of subsidy status, plant age, plant location, energy source and renewable generation technology). In addition, standards should stipulate that the quality of the electricity purchased must be reported on as part of accompanying information to the emission inventory.

Adaptability to market developments

Another advantage of the market-based approach is its adaptability to market developments: using EACs, not only can the renewable attributes be transferred as part of a PPA, but granular verification in terms of location and time could in principle also be implemented. This is becoming increasingly important, for example, in view of the developments in the context of the regulations on RFNBO (Renewable Fuels of Non-Biological Origin, such as hydrogen) and the strict additionality criteria for the generation of electricity in the context of green hydrogen verification (defined by Delegated Regulation (EU) 2023/1184 of the EU Commission)[11] .

[11] Commission Delegated Regulation (EU) 2023/1184 of 10 February 2023 supplementing Directive (EU) 2018/2001 of the European Parliament and of the Council by establishing a Union methodology setting out detailed rules for the production of renewable liquid or gaseous transport fuels of non-biogenic origin.



Hamburg Institut, 2024

Illustration 3: Proposal for electricity accounting following a market-based approach

Implementation of the proposed solution in practice
Specifically, the proposal for a consistent application of the market-based approach would mean that, as shown in Illustration 3, at least in EU markets or markets that are part of the European GO system (also including NO, IS, CH) only the market-based approach would be used in GHG accounting. Emission factors would be derived on the basis of the available contractual instruments – in the European electricity market primarily electricity disclosure information, with RES quantities being verified with GO cancellation. If this is not possible, the residual mix is used.

International applicability of the market-based approach
The international applicability of the market-based approach harbours challenges: adequate verification systems for RES that lead to robust contractual instruments meeting the quality criteria are not established everywhere. If the electricity market in which a company, and therefore its electricity procurement, is located is outside of the European electricity market, then – as shown in Illustration 3 – it is necessary to check whether possible contractual instruments are compatible with the corresponding quality criteria for a market-based accounting approach.

If this is the case, the emission factor can also be determined based on the attributes of electricity supply, which are transferred via the corresponding contractual instrument.

If there is no adequate verification system and therefore no admissible contractual instrument, the location-based approach should be used. In this way, double counting can be avoided, as one approach is then used consistently in delimited electricity markets.

In any case, the methodological decisions should be documented and made transparent.

Independent review through international initiatives
The challenge here lies in assessing other verification systems: this requires identifying, understanding and analysing corresponding regulatory provisions or standards. Moreover, it is almost impossible to assess on a case-by-case basis what the practical implementation of the verification system looks like.

In addition, there is a risk of double counting if different actors come to different conclusions regarding the applicability of the market-based approach for a market region.

One possible solution could be the accreditation of corresponding verification systems by international centralised bodies on the basis of an independent audit, e.g. through an international standard initiative. In order to establish clarity regarding the applicability of the market-based approach, it could also be advantageous in the future to institutionally anchor a corresponding audit at an international intergovernmental organisation, such as the International Renewable Energy Agency (IRENA).

6 OUTLOOK: PROSPECTS FOR FURTHER DEVELOPMENT IN THE USE OF THE MARKET-BASED APPROACH

Does the preference and focus on the market-based approach proposed here and its consistent use solve all the challenges in accounting for electricity procurement? Certainly not. For one, the design of the market-based approach can be discussed with regard to the quality criteria for market-based instruments. For example, the criteria should be supplemented by the aspect that **market-based instruments need to be accompanied by an energy disclosure obligation in the market region**, as otherwise double marketing of RES volumes cannot be reliably prevented (see also RE-DISS II (2014) or the recommendations of the Hamburg Institute in the GHG Protocol Review process (Styles et al. 2023b)).

Why the risk of double counting still exists

LCA databases still use location-based data to account for energy inputs in the production process. To avoid double counting of green attributes along the entire value chain, Holzapfel et al. (2023; 2024) therefore suggest using the attributes of the residual mix in LCA databases instead of location-based data, as this ensures that they have not been explicitly assigned to a specific electricity consumption. However, a residual mix is not published in every country. For 34 countries in Europe that are members of the European Energy Certificate System (EECS) of the Association of Issuing Bodies (AIB), residual mix information is provided by the AIB (Association of Issuing Bodies 2024). One challenge, however, is dealing with countries with full disclosure requirements (such as Austria and Switzerland), as there are no energy attributes here that have not been tracked and therefore no residual mix.

> In the future, this problem could be solved by **recording GHG emissions** along the value chain **based on primary data.**

If every company were to prepare PCFs using the market-based approach, a consistent application of the market-based approach along the entire value chain of a product would be ensured. Emissions associated with preliminary products or materials reported on under Scope 3 (i.e. indirect emissions arising in the upstream and downstream supply chain) then would also be based on a market-based accounting of the energy inputs required to manufacture them.

In this case, it would no longer be necessary to use default values from databases. An exception would be geographical regions without a RES verification system that meets the quality criteria for a market-based balancing approach: here, until such a system is established, accounting would be based on a standardised location-based approach. However, such a consistent solution is currently still a future scenario.

For the special case of European countries with full disclosure requirements without a residual mix, it would be conceivable as a makeshift solution to **use the European residual mix as a standard factor in LCA databases, for example** (see also Holzapfel et al. 2024). This shows that even more far-reaching adjustments beyond the accounting methodology are required in order to achieve an accurate, reliable and comparable methodology for energy accounting.

Why granular EACs could contribute to the further development of the market-based approach

Granular EACs represent an opportunity to respond to electricity market conditions as well as grid restrictions and to bring the location-based and market-based balancing approaches closer together again.

A frequent point of criticism of the current design of the market-based approach concerns its **temporal and spatial resolution**. For one, disclosure obligations generally specify an annual matching of attribute supply and demand. For the other, the definition of a market region for disclosing the attributes of electricity supply (e.g. the European internal market in the European Guarantees of Origin system) tends to abstract from restrictions in the grid infrastructure, such as grid congestion or limited capacities of cross-border interconnectors.

A higher spatial granularity can largely be mapped with the existing information on EACs regarding the plant location, supplemented by a comparison with information on bidding zones with a uniform electricity price, or grid and interconnector bottlenecks – e.g. via grid traffic lights (see Schleswig-Holstein Grid 2024). However, this increases the disclosure effort. However, the greater scarcity of EACs within the geographical area relevant to a company's electricity demand could **increase the value of green electricity** from the corresponding region, **with more effective RES expansion impulses**.[12] In addition, a shift in demand to times without transmission bottlenecks might be stimulated, i.e. a more grid-friendly consumption behaviour.

With regard to temporal granularity, energy system modelling studies indicate that **hourly matching of electricity demand and consumption in energy disclosure** can be significantly more effective in reducing greenhouse gas emissions than is the case with annual balancing (see e.g. Langer et al. 2024; Zeyen et al. 2022). This is particularly the case for green hydrogen production or other electricity-intensive industrial processes: without aligning electricity demand with the availability of renewable energy, electricity consumption can lead to an increase in electricity generation based on fossil fuels in the respective hours, with a corresponding increase in GHG emissions. The proposal to switch to hourly or even quarter-hourly matching of electricity generation from renewable energies and consumption in GHG accounting, or at least to show the proportion of correspondingly matched energy attributes in the electricity consumption of companies, is also being discussed as part of the revision of the Scope 2 Guidance of the GHG Protocol (Fisher et al. 2024).

However, a higher temporal granularity of EAC issuance and cancellation requires a further development of centralised, usually national EAC registries in Europe, or a coupling of such registries with granular EAC systems in order to exclude double counting (EnergyTag 2024). There are also increased requirements for the digitalisation and automation of verification and disclosure processes at the level of electricity producers, traders and electricity consumers.

> Nevertheless, this represents an important development perspective for the market-based approach: EACs of higher granularity open up the possibility of visualising the **temporal and spatial correlation of consumption and generation**. In this way, physical realities can be better mapped. The market-based approach and the location-based approach are thus moving closer together and the advantages of both approaches in relation to electricity accounting could be combined.

[12] In Germany, the Renewable Energy Act's double marketing ban precludes the issuing of GOs for subsidised renewable energy production. Here, an alignment of the market- and location-based approaches by means of granular EACs would only be possible for a small part of RES production – namely unsubsidised production.

In theory, the energy-intensive company from the initial example could use granular GOs to claim the renewable electricity from Schleswig-Holstein in its GHG emission inventory that was actually produced in the region at the time of electricity consumption. However, in Germany the Renewable Energy Act's double marketing ban poses a problem here, according to which GOs may not be issued for subsidised plants. As a large proportion of renewable energy production in Germany is subsidised, it could be the case that the quantities of renewable energy available in SH for which (granular) GOs could be issued are not sufficient to cover the company's electricity consumption.

How the market-based approach can be extended to heating and gases (biogas, hydrogen)

The market-based accounting approach can also be applied to other energy carriers. With the implementation of RED II from 2018 in the member states, the European GO system will be extended to gases (including hydrogen), heating and cooling. Here too, potential verification mechanisms are emerging that could fulfil the quality criteria for market-based instruments, provided that there is coordination with existing verification systems (e.g. the mass balance system in the biogas sector).

Purchased heating and cooling (such as district heating) would fall under the regulations on accounting for purchased energy in Scope 2, which currently have a strong focus on electricity. For example, a concise annex to the GHG Protocol Scope 2 Guidance allows the market-based approach to be applied to district heating purchases in the same way as electricity. Compared to electricity, however, the district heating market has specific characteristics that result, for example, from the frequent monopoly position of suppliers and the physically closed and geographically limited nature of supply systems (compared to the widely interconnected electricity system). These should be taken into account in the design of verification and disclosure systems and in quality criteria for market-based instruments (Styles and Claas-Reuther 2023). For example, credibility risks arise if EACs are traded across the boundaries of non-interconnected district heating systems for disclosure purposes, as energy cannot even theoretically be supplied here. When disclosing the attributes of heating supply, it would therefore make sense to **establish a higher level of spatial granularity** from the outset or to strive for an integration of location-based and market-based approaches, i.e. to use the market-based approach within the boundaries of interconnected supply systems.

For the purchase of gases (e.g. biomethane and hydrogen), the application of the market-based approach is also conceivable, with corresponding verification. In addition to EAC systems, a central mass balance registry for an energy market region can also fulfil this task for gases and liquid fuels, such as the EU's Union Database, which is currently being implemented. One challenge, however, is that the purchase of biomethane – even if it is purchased via the gas grid – is subject to Scope 1 accounting, as the energy production from the gas and the associated GHG emissions are generated by the reporting organisation itself, rather than by energy generation plants feeding into the grid as in the electricity sector. Under the GHG Protocol, the application of the market-based approach is currently only intended for Scope 2 (World Resources Institute 2023a).

The same applies to the purchase of hydrogen as an energy source, the green properties of which (when produced on the basis of electricity from renewable energies) could then be accounted for in Scope 3 on a market-based basis given corresponding proof.

In the context of the GHG Protocol review process, the application of the market-based approach is also being discussed for the accounting of Scope 1 and Scope 3 emissions (World Resources Institute 2024).

> Market-based mechanisms offer the possibility, beyond the verification of energy properties, to also serve as a verification system for other material flows that are included in the footprint calculation (especially in the primary commodities industry, e.g. in relation to green steel or chemicals produced in a particularly climate-friendly way). There is great potential here to make GHG accounting more precise and transparent and to avoid double counting of green attributes.

Why EACs should only be a verification tool and not a policy instrument

An accounting methodology alone cannot fulfil all the demands placed on it. For example, the incentivisation of emission reductions and the evaluation of companies' procurement decisions should be regulated outside the accounting methodology, so that GHG accounting remains primarily a monitoring tool and EACs primarily a verification tool and not a policy instrument. In this way, GHG accounting approaches and RES verification systems have the potential to be harmonised and serve as a transparent and verified data and assessment basis in a wide variety of contexts.

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