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Data Specificity in Scope 2 Accounting for Carbon Reporting: A Case Study Using Internet of Things-supported Electricity Measurements

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***Abstract* – Among growing regulatory and investor pressure for high-quality sustainability reporting, accurate carbon accounting has become essential for corporate environmental, social, and governance disclosures. A key challenge exists in calculating Scope 2 emissions, where companies often use generalized national average emission factors, for which accounting approaches differ in how electricity generation, cross-border exchanges, and energy attributes are interpreted and allocated. This study critically reviews literature on data specificity in Scope 2 accounting, analysing methodological differences between location-based mix and market-based mix approaches defined by GHG Protocol, the role of residual mixes and current spatial and temporal shortcomings of methods related to calculation of life cycle assessment and environmental product declarations. This study aims to explore how an increase in the granularity of company-specific electricity consumption measured data can improve the precision and traceability of related Scope 2 emissions for more qualitative operational decisions in companies. A case study was conducted using hourly electricity consumption data from four manufacturing companies that operate in Latvia over one year. The delivered electricity mix was recorded each hour, and company-specific average hourly and yearly emission factors were calculated based on energy source types. The results demonstrate that company-specific data typically yield lower calculated emissions compared to using *Ecoinvent* 3.11 database country-specific emission factors. However, these results must further be contextualized within the methodological tensions between physical location-based and contractual market-based accounting. This study supports the current need for harmonized, high-resolution electricity data practices and integration with digital solutions to support trustworthy carbon emissions disclosures.**

***Keywords* – Corporate sustainability reporting; energy mix; EPD; ESG; GHG Protocol; green certificates; guarantees of origin; IoT; LCA.**

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1. INTRODUCTION

Climate change and increased public attention are gradually driving the demand for transparent and high-quality corporate sustainability (especially carbon) reporting [1], [2]. Certain governments are trying to incorporate formerly voluntary Environmental, Social, and Governance (ESG) disclosures into mandatory legal requirements. In European Union (EU), the already operating Corporate Sustainability Reporting Directive (CSRD) (Directive 2022/2464) demands high number of companies to report detailed ESG data [3], using standardized European Sustainability Reporting Standards (ESRS) [4]. Complementary, but no less important EU regulations in this field like Sustainable Finance Disclosure Regulation (SFDR) and EU Taxonomy for sustainable activities further demand accurate climate-related data to inform investors and ensure compliance [5]–[7]. International Sustainability Standards Board (ISSB) issued its first IFRS Sustainability Disclosure Standards (IFRS S1 and S2) already in 2023 as a global baseline for climate and sustainability reporting [8]. These standards indicate a new stage where companies must provide consistent and comparable climate data [9]. Voluntary frameworks remain influential as well, for example, the Global Reporting Initiative (GRI) and Greenhouse Gas Protocol (GHG Protocol) continue to raise the bar on disclosure detail. Increasing amount of more detailed life cycle assessment (LCA) frameworks are developed, for example, dynamic LCA [10], the results of which would directly affect the company's environmental performance. This can be combined in the overall trend: both regulators and investors now expect more clear and higher-precision ESG data similar to data used in financial reporting [11].

Main focus of these emerging requirements is company level greenhouse gas (GHG) emissions, especially those arising from energy consumption. Energy-related GHG emissions accounted for 42.6 Gt CO_2eq in 2024 (consequently, making this sector the largest contributor to climate change), with electricity generation alone contributing about 40 % of sectoral emissions [12]. It must be mentioned that emissions from purchased electricity categorized as Scope 2 (indirect emissions) in the GHG Protocol [13] will be further studied in this article.

The precision of energy-related emission calculations has become a pressing issue [14]. Historically, companies and LCA practitioners often relied on generic or averaged data such as national grid-average emission factors to estimate carbon footprints. However, such low-resolution, generalized data may not reflect considerable variability. Recent analyses demonstrate that using broad averages versus granular, location or supplier-specific data can lead to completely different GHG emissions results [15]. In the context of strict new reporting rules, there is a growing consensus that carbon accounting must transform from general assumptions to precise, granular data in order to support trustworthy sustainability claims [11], [16]. The aim of this study is to show how increasing the granularity of company-specific electricity consumption data can enhance the accuracy and traceability of Scope 2 emissions, thereby supporting more informed and higher-quality operational decision-making within companies. To achieve this, firstly, a critical review of the literature is performed to assess the need for improved data precision in ESG (and associated) reporting, with a focus on carbon emissions from energy use and secondly a case study is presented where four manufacturing companies' (operating in Latvia) hourly electricity consumption data is analysed. Internet of Things (IoT) sensors as increasingly popular solutions in smart electricity grid monitoring [17], are used in this study to record a specific amount of electricity consumed in a specified time interval (one hour), as well as send this data to software that calculates emissions from electricity use in real time.

2. Literature Review

2.1. Drivers for High-Precision ESG Reporting

Regulatory and voluntary sustainability reporting frameworks continue to increase the need for accurate, auditable ESG data, which in turn pressures companies to improve the quality and precision of their emissions calculations. In the EU, it can be generally said that the CSRD indicated a paradigm shift by moving sustainability reporting from voluntary status to a legal requirement [11]. Under the CSRD, companies must follow detailed ESRS that specify exactly how to measure and disclose ESG metrics, including GHG emissions. However, EU has also adopted Omnibus simplification initiatives [18] postponing the application of CSRD requirements for certain companies considering the need to minimize administrative and reporting burdens which indirectly indicate that perhaps more automated and digitalized solutions are needed to facilitate and increase sustainability data accuracy and granularity to make it less complex for companies to comply with reporting requirements.

In the context of both the need to reduce administrative tasks and also the eventual need to comply with the CSRD requirements, new data systems (potentially involving such devices as IoT sensors) to automatically collect site-level sustainability (or the opposite) data in real time might be one of the solutions how to increase the knowledge on company's ESG performance without significant additional manual labour.

Carbon Disclosure Project (non-profit organization whose reporting guidelines follow GHG Protocol [19]) questionnaires asks companies to report emissions reductions from renewable energy procurement separately, pushing reporters to distinguish between market-based renewable use and location-based method. So, the GHG Protocol's developed methodology foresees accounting of emissions based on two different principles – one is based on purchased electricity and the remaining part for which no energy certificates or guarantees of origin are issued (so called market-based mix, where each renewable energy guarantees of origin or certificates are sold and purchased, and residual mix constitutes of remaining electricity for which any guarantees or certificates are not sold) and the other is based on the generation location (so called location-based mix, where each countries or regions produced electricity is attributed to that territory) [13]. It must be mentioned that typically residual mixes consist of significantly more percentage of non-renewable sourced electricity [20].

Considering previously discussed arguments, it could be beneficial for companies willing to improve their ESG performance to move their sustainability reporting toward standardized, auditable data already today and also in near future. This context identifies the opportunities for improving data precision (especially for electricity related emissions). From the regulatory compliance perspective also PricewaterhouseCoopers survey should be mentioned which shows that data quality and controls have become top concerns for CSRD compliance, with companies mentioning data availability and quality as a primary challenge in meeting the new rules [21]. Thus, the voluntary increase of ESG data granularity and also evolving regulatory landscape promotes the fact that companies want to upgrade their data collection and calculation approaches to produce verifiable, accurate and company-specific ESG data.

2.2. Energy-Related Emissions: Data Resolution Challenges

Energy consumption, particularly electricity use, is often one of the largest contributors to a company's carbon footprint, making the handling of its emissions data important in ESG reporting [16] since the (efficient) use of electricity can be controlled by the company itself. Electricity generation accounts for the single biggest share of global energy-related GHG emissions (on the order of one-third to two-fifths depending on the year) [12]. For many

organizations, especially energy-intense manufacturing companies, purchased electricity (Scope 2) can exceed direct (Scope 1) emissions [22]. Thus, the precision of electricity emissions accounting that is in a direct control of the company has a large effect on the overall accuracy of sustainability reports. However, an existing challenge is that electricity's carbon intensity varies widely across geographic locations, technologies, and timescales, whereas reporting has traditionally used simplified static average factors [16].

Most LCA databases such as *Ecoinvent* [23], *Sphera* [24] or *OpenLCA Nexus* [25] use national or regional average emission factors, e.g., an average CO_2eq per kWh or MWh for a country's grid, to calculate emissions (that can be used in ESG data calculation). While convenient, this approach can severely misrepresent the actual emissions associated with a specific manufacturing facility or product. For example, an industrial manufacturing company in France using mainly hydroelectricity would have a much lower real carbon impact than the EU average grid mix, whereas factory in Poland (with coal used for electricity generation) might be underestimating its impact if using generic EU factor [26]. Grid CO_2 intensity fluctuates hourly and seasonally as renewable generation shift. Similarly, companies purchasing renewable energy certificates (or guarantees of origin) may in reality be using low-carbon electricity, yet a location-based method might assign them too high average grid emission factor (for example, the use of EU average factor), overstating their carbon footprint [16]. On the other hand, if a company uses mostly fossil-based electricity in a relatively green-grid country (for example, Latvia), the national average could underestimate its emissions. Thus, it can be seen that the underlying emission factors of the two existing reporting methods under the GHG Protocol could be improved if the data granularity is increased and company-specific data would be considered in emissions calculations.

The available literature also describes examples of discrepancies regarding choice of emission factors in LCA studies. Ghosh *et al*. showed that in the United States, life cycle emission factors for electricity can differ significantly across regions due to differences in generation mix and technologies [27]. The authors conclude that spatially relevant electricity data is needed for meaningful life LCA studies and note that uncertainty is high when average data are used [27]. Henriksen *et al*. similarly emphasizes that geographical representativeness is a critical dimension of LCA data quality, because if a process has large regional variability (such as electricity generation), using data without sufficient geographical precision can be unacceptable [28]. In their proposed data quality framework (pedigree matrix) positioned to address temporal, technological and geographical evaluation, the best score for geographical representativeness is given when data come from the specific location and technology, penalties are applied if spatial generalization increases [28].

2.3. Location-Based vs. Market-Based Accounting

A recent critical study [16] described that if one entity uses the market-based approach (claiming guarantees of origin for renewables) while another uses the location-based approach on the same grid, both may count the renewable portion – one via certificates, the other within the average mix [16]. This leads to an inflated total share of renewable consumption. Such inconsistencies can cause underestimation of impacts (since renewable part is counted twice) [16]. The authors in the mentioned study identified this parallel use of methods (without appropriate adjustments and clear methodological boundaries) as the main double counting challenge in GHG accounting and urged that a very careful separation of who "owns" the renewables and consistent accounting with clear boundaries is used [16].

The need for harmonization is also mentioned by Dyck *et al*. who found that modelling a company's electricity consumption with the market-based residual mix versus location-based

production mix can create substantially different outcomes. For example, in Norway's case, using the residual mix (which assumes the hydro guarantees of origin are exported) led to impact scores ~5000 times higher than using the location-based mix (where the emission factor is 0 g CO_2eq/kWh) [15]. This amount of difference shows how different results calculated with different accounting methods can create uncertainties leading to incorrect statements of used electricity's green nature, undermining the credibility of both product LCAs, environmental product declarations (EPD) and then following further also the credibility of ESG reports, in this way increasing the risks of greenwashing [29].

In LCA practice, the issue is especially confusing with LCA databases. For example, *Ecoinvent*, which historically provided average grid mixes for each country/region for use in product assessments, recently has begun to include residual grid mixes reflecting electricity after certificate trading [23].

For example, when every consumer sticks to the location-based method, the shares of renewable and conventional energy in each assessment match the actual generation split (e.g. 45 % renewable system yields 45 % renewable in each user's accounting) [30]. If every consumer used market-based accounting only, and guarantees of origin were correctly allocated, the sum of all guarantees of origin would still equal the actual green generation (45 %) [30]. The problem starts when some use location-based and others use market-based method without clear and appropriate coordination. For example, Company A buys guarantees of origin for an amount equal to 45 % of the grid's power and reports that as 100 % renewable usage (market-based method). The remaining consumers, unaware or not using guarantees of origin, might each report 45 % renewable in their consumed mix (location-based method) [30]. This describes the need for careful accounting and disclosure. The consequence is underestimation of emissions, because total Scope 2 emissions reported by all parties would be lower than actual.

In the ongoing public consultation on the revision of the GHG Protocol, stakeholders are also discussing how to improve the overall consistency of two reporting methods and also how to correctly define the requirement to use the most accurate location-based emission factor possible (possibly prioritizing hourly emission factors [31]), as well as how to increase the accuracy of market-based accounting, for example, by specifying that all certificates (or guarantees) used must be matched on a hourly basis, that purchased green electricity must be physically deliverable, as well as what changes are needed in the definition of residual mix [32]. In this light, the real-time measurements of consumed energy and its associated emissions could provide plausible solution for the lack of reliable data on the origin of the energy consumed to support market and location-based methods [32].

2.4. Limitations of Current LCA and EPD Frameworks

While accounting methods are one aspect, LCAs and EPDs could also be improved by increasing the temporal and spatial resolution needed to represent actual energy use and emissions.

In order to improve life cycle impact calculations this in practice identifies the need to use more granular data by shifting from the use of average emission factors for the product's life cycle inventory [23]. Today, EPD (or digital product passport (DPP) consisting of EPD [33]) represents a static moment not showing whether production happens at noon or midnight, or in summer or winter. If a company (manufacturer) shifts energy-intensive processes to times of surplus renewable generation, the current LCA methods would hardly register the benefit unless time-specific (or company-specific) data is used. Likewise, location averaging in EPDs

cannot show differences happening in a single country, for example, northern and southern Italy may have different grid mixes, but an Italian average may be applied uniformly [34], [35]. If more company-specific data would be used to calculate the impacts, the results could be more precise.

Overall, the temporal and spatial averaging leads to reduced accuracy and credibility of LCA results, (also affecting the information shown in EPDs), and can even mislead decision-makers [36]. As a solution, a type of research on dynamic LCA has emerged [36]–[38].

Typically, generic LCA might overestimate impacts if the real process uses cleaner energy than the average, or underestimate if more fossil-based energy is used. Dynamic LCA may use time-series for electricity grids to reflect decarbonization tendencies or hourly, seasonal variability by use of hourly resolution data with corresponding hourly emission factors [36]. Lueddeckens *et al*. found out that applying dynamic inventory or characterization can significantly improve accuracy of LCA results, especially for carbon emissions where timing matters (the alignment with periods of low or high grid carbon intensity) [38].

The implementation of DPPs as part of the EU's circular economy efforts is being looked at with hope to solve these temporal and spatial-related emission estimation issues. A DPP is a digital record attached to a product holding information about its materials, origin, and environmental footprint [33]. The aim of these passports is to enable consumers and regulators to verify environmental claims made by the manufacturer [33].

DPPs could also allow more real-time updating of product data instead of a static one-time EPD. A passport might be updated periodically (or even continuously for some metrics) to reflect current performance or impact of a current batch of a product. This would be relevant for wide range of product categories, for example, not only for products that are manufactured in large batches (like fast-moving consumer goods, solar panels, electronic devices, etc.), but also for products like electric vehicle batteries or buildings, whose life cycle impact can depend on the changing grid mix during use.

There is a growing recognition that to support claims made in DPPs or other documentation, LCA data needs to become more site-specific and time specific [36]. If such evolution will not happen, companies risk making claims that, while compliant on paper, in reality they do not hold up to claimed performance, thus a form of unintentional greenwashing through data omission and limitations of current datasets forms. To bridge this gap, advanced digital solutions could be deployed [39], as will be discussed next.

2.5. Digitalization for Traceable, High-Resolution Energy Data

Emerging digital technologies offer new ways to collect and verify energy-related emissions data with unprecedented granularity. The integration of these technologies into LCA, EPDs and other types of environmental assessments and documentation is developing fast, with the promise of addressing many challenges outlined previously. Popowicz et al. (2025) in a recent critical review surveyed over 100 studies on digitalization in LCA and found that IoT, big data analytics, artificial intelligence, and blockchain have all been applied in various ways [40].

IoT is primarily used in the inventory analysis phase of LCA to automatically gather real-time data on resource and energy flows [40]. By using smart meters and sensors on equipment, companies can continuously record actual electricity, material consumption, fuel use, and process outputs (waste), rather than relying on industry-average estimates. This real-time data capture can significantly improve the accuracy of the life cycle inventory, which, as noted by Miah *et al*., is where 70–80 % of LCA effort and also uncertainty lies [41]. For example, an IoT-based system in a manufacturing site could log electricity use in 15-minute or hourly intervals and associate it with production batches. The ability to tie emissions directly to

specific process conditions or times can highlight improvement opportunities that static LCA cannot.

By continuously measuring actual energy consumption and recording the generation source (if linked to grid data and green certificate accounting systems), these IoT meters could eliminate the reliance on proxies and averages. If each manufacturing site or machine had such a meter streaming data to an ESG platform, a company's Scope 2 emissions could be calculated with near-real-time precision (regardless of the accounting method used).

Case studies already show that real-time, granular energy data leads to more accurate carbon assessments [42]. Measurements at a manufacturing site might reveal, for example, that certain percentage of its annual electricity was consumed in just a few peak weeks of production, then with granular data, the company could target those weeks and shift loads to other weeks or use renewable-powered batteries, solar photovoltaics. Traditional annual averages would not capture such details. This points toward a future where carbon accounting is continuous rather than periodic, and where emission reductions from efficiency or switching to green energy can be observed instantaneously, not months or years after the fact. The incentive to switch to more green energy or renewable self-generation also can be promoted if methodologies for location-based emission factors are improved and more widespread, and reliable and accountable use of location-based factors are implemented.

However, despite the promise of digital devices, significant gaps and challenges remain before smart meter data can be fully integrated into GHG accounting. An identified gap is measurement frequency versus effort: how granular is granular enough? There is limited research on the marginal benefit of hourly vs. daily vs. monthly data granularity and impact of LCA or EPD results. Stakeholders in the public consultation of GHG Protocol revision are discussing these temporal granularity issues, for example, the use of load profiles to estimate hourly consumption from annual data in case no hourly data is available. Challenges regarding the selection of publicly available, applicable and methodologically correct emission factors are discussed as well [32]. The practical balance between these possible new requirements and existing or new digital technologies that could provide necessary data is a research gap that is not widely addressed in existing literature yet.

3. Methodology for Case Study on Company-Specific Hourly Electricity Emission Factors

Data on hourly electricity consumption for four different manufacturing companies operating in Latvia was collected during the year of 2025 (see Fig. 1 for schematic overview of case study's methodology). Company A operates in metal industry, Company B – in printing, whereas Company C produces wood panels, but Company D – heavy machinery. AdvanGrid GridLink and GridMate wireless sensors, together with AdvanGrid's energy management software platform, were used to measure electricity consumption and electrical parameters at the monitored facilities. The sensors provide high-frequency measurements of voltage, current, active and reactive power, total harmonic distortion, frequency and power factor, with data transmitted at intervals of up to approximately five seconds. Therefore, following recordings were made:

- energy source country,
- type (e.g., hydro run-of-river, wind onshore, fossil gas etc.),
- exact quantity from specific energy source,
- energy consumed in kWh,

– related kg CO_2eq emissions (the electricity consumption was measured hourly at each company and then it was combined with the corresponding hourly electricity mix derived from the ENTSO-E Transparency Platform [43], [44]. Electricity generation technologies were mapped to corresponding processes in the *Ecoinvent* 3.11 database. Life cycle GHG emission factors, expressed as kg CO_2eq/kWh using the IPCC 100-year global warming potential, were then applied to calculate the associated hourly GHG emissions).

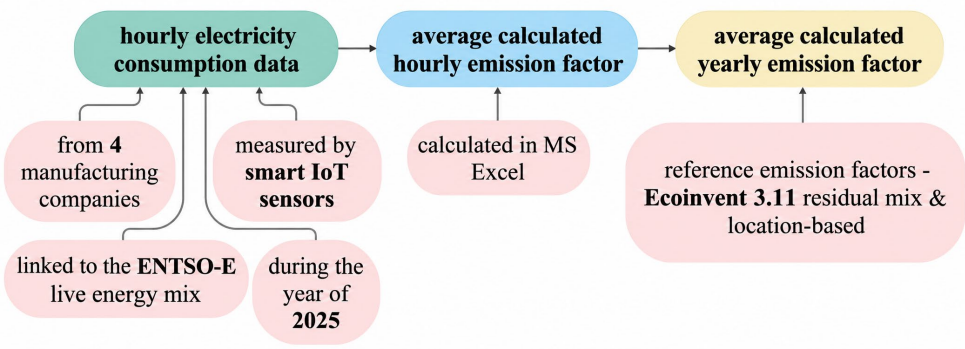


Fig. 1. Case study's methodological approach.

Further on, data was processed in MS Excel – firstly, it was filtered by date, time and consecutively electricity consumed and associated sum of CO_2eq. For companies that had two electricity inlets, data on consumed electricity and sum of CO_2eq were respectively summed together by month. Descriptive statistical method – average value calculation was used to determine average calculated hourly emission factor values on a monthly basis. Further, from these average values yearly average value was calculated.

Ecoinvent 3.11 database (Scope 2 all GHGs CO_2eq) was used to represent reference emission factors for Latvia (year 2025) [23]. Market-based factor is represented by residual mix. No further calculations or adjustments from the emission factor values provided in the *Ecoinvent* 3.11 were made – the values were used as presented in the database.

4. Results

4.1. Case Study Results

Fig. 2 shows monthly electricity consumption for four companies analysed. It can be seen that Company A typically consumes more electricity than other companies, but Company B uses the least amount of electricity among analysed companies.

Summer and winter manufacturing breaks can also be observed in July and December for Company A. Fig. 3 shows average calculated hourly emission factors based on 2025 data and *Ecoinvent* location-based factor (shown in red). The *Ecoinvent* factor (electricity, medium voltage, residual mix for Latvia; expressed as *Ecoinvent* residual mix factor further in text) is shown in gray.

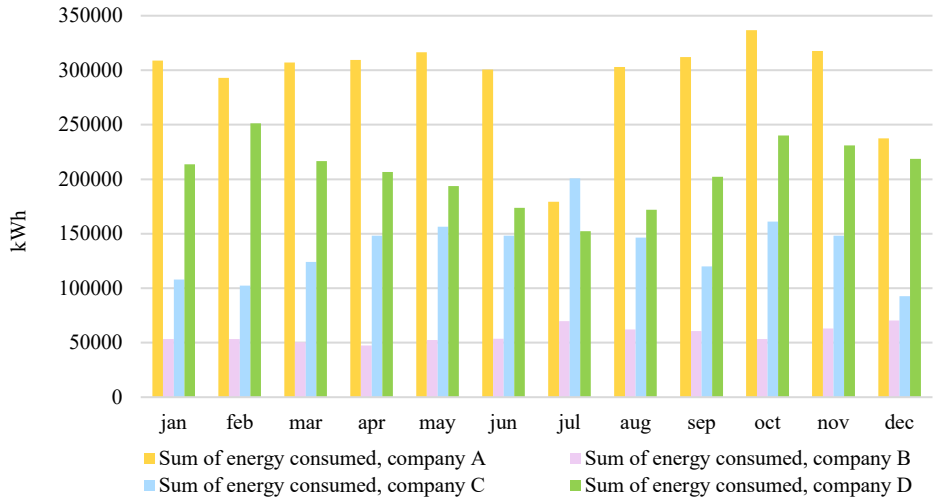


Fig. 2. Electricity consumed by analysed companies in 2025.

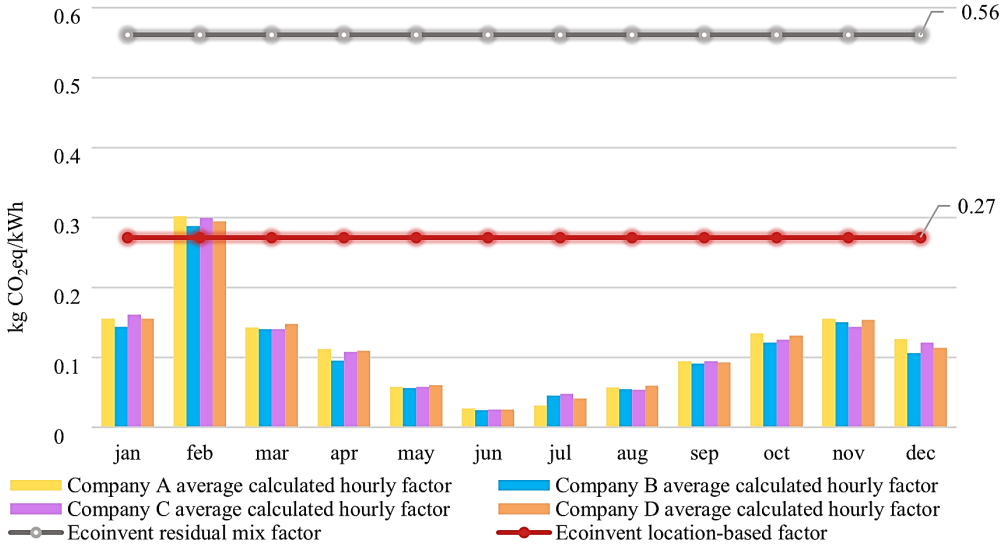


Fig. 3. Average calculated hourly emission factors, *Ecoinvent* location-based factor and *Ecoinvent* residual mix factor in 2025.

It can be seen from Fig. 3 that only in February 2025 average calculated hourly emission factors exceeded *Ecoinvent* location-based factor. The average calculated hourly emission factor for whole year for companies A, C and D would be 0.12 kg CO_2eq/kWh (value rounded up to full hundredths – minor differences in thousands of a decimal point were observed due to the electricity usage patterns), and for company B 0.11 kg CO_2eq/kWh, therefore the difference between company-specific hourly emission factor and *Ecoinvent* location-based factor would be around 0.15 kg CO_2eq/kWh leading to around 125 % CO_2eq emission

overestimation. Though, it must be mentioned that company-specific factors slightly differ between companies on a monthly basis as well which corresponds with the previously mentioned electricity usage patterns (e.g., manufacturing in daytime and nighttime, interruptions in the production process).

Also, it can be seen that in months when renewable generation in Europe is typically lower (late autumn, winter), company specific factors are closer to the *Ecoinvent* location-based factor, for example, emission factor for Company B in January is 0.14 kg CO_2eq/kWh (48 % lower than the *Ecoinvent* location-based factor), but in June – 0.02 kg CO_2eq/kWh (93 % lower than the *Ecoinvent* location-based factor). If company-specific factors are compared to *Ecoinvent* residual mix factor, in all cases the use of this factor would lead to emission overestimation. To analyse the variations between emissions calculated using company-specific, location-based or residual mix factor (in case market-based accounting approach is used and no guarantees of origin are purchased), Figs. 4a, 4b, 4c, 4d were prepared.

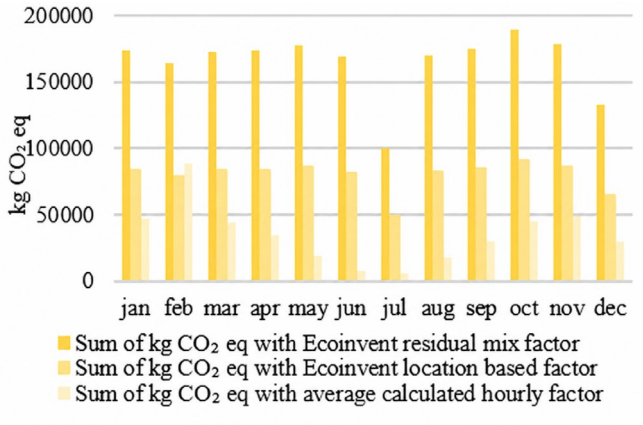


Fig. 4a. Comparison of emissions calculated using *Ecoinvent* location-based factor, *Ecoinvent* residual mix factor and company-specific average calculated hourly factor for Company A.

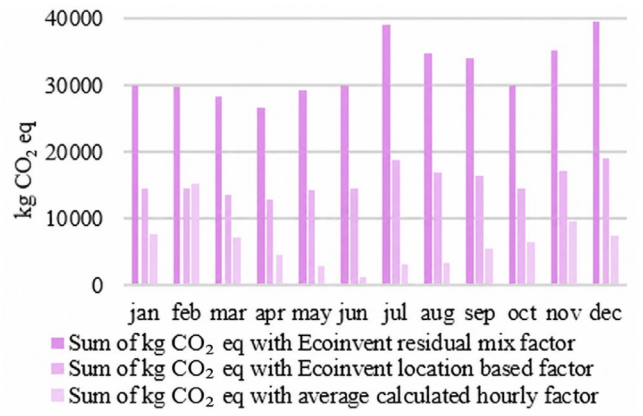


Fig. 4b. Comparison of emissions calculated using *Ecoinvent* location-based factor, *Ecoinvent* residual mix factor and company-specific average calculated hourly factor for Company B

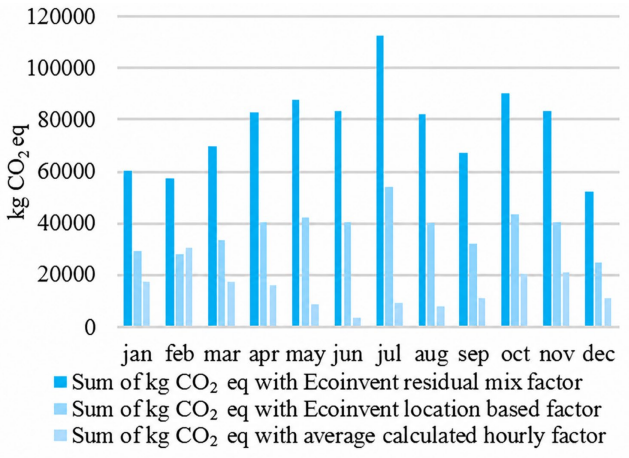


Fig. 4c. Comparison of emissions calculated using *Ecoinvent* location-based factor, *Ecoinvent* residual mix factor and company-specific average calculated hourly factor for Company C.

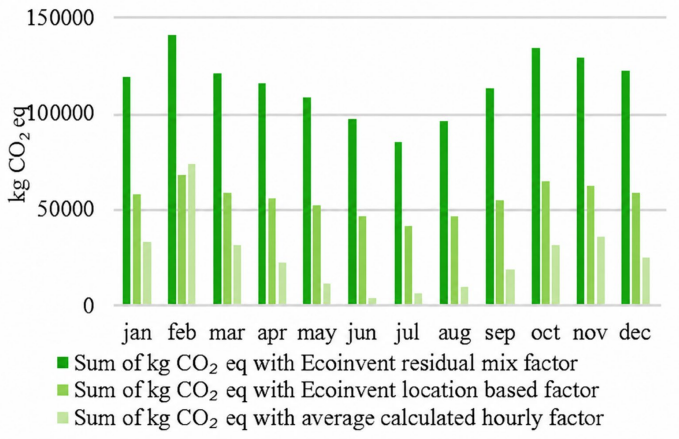


Fig. 4d. Comparison of emissions calculated using *Ecoinvent* location-based factor, *Ecoinvent* residual mix factor and company-specific average calculated hourly factor for Company D.

According to Latvian high-voltage network operator's data, in 2025 Latvia exported guarantees of origin for 2.60 million MWh electricity produced but imported for 0.66 million MWh. Latvia issued guarantees of origin for 3.10 million MWh electricity but used for 1.21 million MWh [45]. This shows that more guarantees of origin were sold than used within the country. In case of market-based accounting, for those companies without purchased guarantees of origin, residual mix emission factor would be applicable.

As the residual mix represents mostly the non-renewable part of the market-based mix [20], the emissions calculated using *Ecoinvent* residual mix factor in Figure 4 are the highest. Nevertheless, the emissions are also higher if *Ecoinvent* location-based factor is used (except for February when the average calculated hourly factors exceeded the *Ecoinvent* location-based factor). Considering all these aspects, the use of company-specific factors clearly provides more granular and realistic results (taking into account company's consumed electricity sources) than in case if the residual mix factor is applied, suggesting that if a certain company wants to improve its emission-related performance, but not only engage in purchase

of guarantees of origin, the solution could be the use of measured company-specific and self-calculated emission factor. Also, this data from Latvia strongly supports the ongoing review of the GHG Protocol's location-based and market-based accounting principles, especially the need to improve location-based accounting methodology.

Some limitations of this study must be addressed:

- regarding timeframe – analysed data covers year 2025, meaning that results from another year could show different situation;
- location-wise – analysed data is from Latvia and companies operating in different regions of Latvia, therefore results for other countries would potentially differ significantly;
- on data precision – measurements were performed within hourly intervals, which means that more or less frequent data registration could also yield different results.

4.2. Discussion

When comparing the results of this study to other published results from the literature, firstly the difference between location-based and market-based accounting methods must be addressed – similarly to this study, Schäfer *et al*. found out that countries where non-fossil sourced electricity constitutes a high share of total generation, emission intensities for location-based or so called generation-based type of electricity are comparatively lower, but the consumption-based emissions are influenced by the flows of electricity to and other countries, meaning that what is generated in the country certainly not always is actually consumed in this country [46]. Secondly, similar tendencies were found in a study [26] regarding emissions from an hourly electricity generation mix in Slovenia and Croatia – lower LCA results for generated electricity were found in cases with a higher percentage of renewables in the electricity mix (depending on day or night time, season), suggesting that location-based method could incentivize carbon-pricing strategies, which could potentially be used by companies to improve their cost-efficiency and location-based emission profile when shifting loads to less emission-intense periods. This study also continues to increase the knowledge of company-specific data use to tackle the methodological differences between location-based and market-based accounting, more extensively analysed by Meng *et al*. [30]. Results of this study support the idea expressed by Meng *et al*. that matching the guarantees of origin with actual recorded consumed electricity data could provide the granularity necessary to keep up with the reporting quality needed under market-based accounting method discussed in GHG Protocol revision's public consultation process [31], [32].

5. CONCLUSION

Emission factors provided in LCA databases or calculated based on national electricity production describe static and averaged situation which cannot provide the granularity needed in emission accounting under evolving regulatory and voluntary reporting frameworks. The case study on four Latvian manufacturing companies showed that smart IoT sensor measured data can be used to determine company-specific hourly carbon emission factors that substantially differ from static emission factors. These results support the idea that in order to improve Scope 2 emissions accounting for improved precision of various environmental documentation, company-specific data which aggregates temporal, spatial and technological aspects could be used. The use of company-specific measured data could minimize greenwashing risks associated with unsubstantiated environmental claims and green energy double counting by registering the specific electricity units consumed by each company and

matching those to the guarantees of origin purchased by company thus improving the market-based accounting method with auditable and measured data. Companies could also be more willing to improve their performance under location-based accounting method (by shifting loads to more green grid conditions or increasing self-generation capacities) if precise data on consumed electricity sources would be available to them.

Future research topics should focus on smart IoT sensor measurement system's applicability in ensuring manufactured products dynamic environmental documentation, also on measured data further analysis (combined with machine learning) to predict future grid conditions for operational decisions. To assure third parties that the data has not been altered, it may be necessary to explore combination of measurement taking and recording using distributed ledger technology.

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