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Advancing Theory and Practice Concerning CO_2e Emissions: A Time-Based Tool for Organisations

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ABSTRACT

Although organisations are increasingly scrutinised on their CO_2e emissions, economic growth is frequently encouraged. Eco-efficiency–based initiatives—'doing more with less'—could be a solution. The problem is that many organisations (e.g., smaller enterprises without access to specialist knowledge) have difficulties in gauging the impact of their initiatives on macrolevel targets of CO_2e reduction. Conversely, a time-based approach, as seen in some social communication tools (e.g., Earth Overshoot Day), is inherently more intuitive, producing a specific date on which organisations cease being sustainable. The problem is that this approach fails to accommodate economic growth in its logic, thus eschewing the benefits growth can bring. In our conceptual article, we develop a simple tool for practitioner use, using a time-based rationale whilst incorporating eco-efficiency principles. In doing so, we advance theory by synergising two different approaches within the sustainable resource use discourse and indicate positive implications for macropolicy development.

Despite the refusal of some political leaders to acknowledge climate change as a problem (Ettinger and Collins 2025), the need for discourse and significant action on CO_2 equivalent (CO_2e) emissions has never been greater. To limit global warming to 1.5°C, the planet must become carbon neutral by 2050 (IPCC 2022), and many countries are setting their own nationally determined contribution (NDC) targets to progressively reduce their CO_2e emissions before then. The United Kingdom, for example, has NDC targets of 68% and 81% (below the 1990 emissions level) for 2030 and 2035, respectively (Department for Energy Security and Net Zero 2025). The current reality, however, is that most targets will almost certainly be missed (UNEP 2024, 2025), and even within countries and regions that are successfully reducing their emissions, the extent to which their individual organisations and specific industries are doing so is widely differentiated. In short, more can be done.

A key underlying barrier to the global progress that is needed is the inevitable link between products and services on the one hand and CO_2e on the other. As consumption of the former accelerates (Cumming and von Cramon-Taubadel 2018; International Energy Agency [IEA] 2025), global emissions of the latter increasingly exceed a 'safe operating space' (IEA 2025; Petersen et al. 2025; Rockström et al. 2009). Although theoretical frameworks and policymaking both aid the development of solutions, ultimately, the onus is largely on organisations to create more 'value' (e.g., products and services) whilst simultaneously reducing their CO_2e (Burgess et al. 2024).

'Doing more with less' (Thorpe 2023) in this way reflects the theoretical simplicity of 'eco-efficiency' (World Business Council for Sustainable Development 1996, 2000), which, as a strategy for sustainable development (Koskela and Vehmas 2012), underpins a number of robust theoretical frameworks such as the circular economy (Pearce and Turner 1990) and operational eco-efficiency (Figge and Thorpe 2023)—all of which, importantly, accommodate economic growth and its associated benefits for wider society (Adams 2004; Lee and Sissons 2016).

In practice, however, operationalising such frameworks can be problematic, with additional issues occurring around measurement techniques: Managers are frequently overwhelmed by the practical challenges of implementation (e.g., Bleischwitz et al. 2022; Bressanelli et al. 2019; Hopkinson et al. 2018), and a dearth of user-friendly and cost-sensitive self-assessment tools (Figge et al. 2018) means that smaller organisations, for example, are often unable to adequately gauge their year on year contributions to national targets, so that they might monitor their progress or, indeed, lack of it.

In contrast to eco-efficiency, time-based approaches are more straightforward in both theory and practice and thus might be an attractive alternative. The rationale is that merely using resources for longer contributes to a more sustainable use (Figge et al. 2018). In the context of CO_2e, this means that after calculating the quantity of emissions that falls within a globally safe operating space (Rockström et al. 2009), they must 'last' organisations (collectively) for a longer period. For practitioners, this could mean something as straightforward as reducing the extent to which their buildings are heated, cooled or ventilated (Shen et al. 2024). However, the simplifying role that 'time'-based approaches can play in making the measurement of CO_2e emissions more meaningful is arguably even more impactful within the context of the challenges that practitioners experience. Specifically, the construct of 'time' can help make abstract data more accessible; outputs from CO_2e assessments become more cognitively relevant for managers. Lee et al. (2021) illustrate this in principle by calculating the ecological footprint of Taiwan for 2018. The output—6.46 gha per person—is arguably meaningless without specialist knowledge. However, the figure becomes less ambiguous following its translation into an 'overshoot' date of 14 March, with clear and meaningful implications, that is, that by this date, Taiwan had used all the natural resources that it could regenerate in 2018 (Lee et al. 2021).

Drawing on time-based social communication tools in this way might encourage the ontological shift that is needed for some managers to act: Not only are CO_2e emissions more easily understood but they also move from being an abstract entity 'over there' to something that is more tangibly relevant, or 'over here' (Ergene et al. 2021; Good and Thorpe 2020; Nadegger 2023). Yet, importantly, the primary disadvantage with pursuing a time-based approach alone is that economic growth, and its associated benefits for society are not accommodated within its logic—in contrast to eco-efficiency.

In this conceptual paper, we move beyond an 'either/or' distinction between the two approaches—time-based and eco-efficiency—to amalgamate them into a single 'with/and' logic to exploit the strengths and negate the weaknesses of both. Our question is *how can a time-based approach to address CO_2e emissions also accommodate the production of goods and services*. To respond, we take the view that CO_2e emissions have a value attached to them as they contribute to the production of consumer products and services. As such, we frame CO_2e emissions as a resource (Ayres and Kneese 1969). We advance theory on the tension between unsustainable consumption on the one hand, and the limited amount of CO_2e emissions that constitute a 'safe operating space' (Rockström et al. 2009) on the other, by moving beyond eco-efficiency per se. Specifically, our theoretical contribution pivots on the inclusion of a temporal dimension whilst still freely allowing for economic growth. Importantly, we theorise 'time' not as a conceptual appendage to some eco-efficiency based approaches, as some previous work has done (e.g., Figge et al. 2018), Rather, the notions of both 'time' (Ancona et al. 2001) and growth are core.

As a specific output to our theorising, we offer a straightforward yet powerfully comprehensive indicator for practitioners to use, regardless of their skillset or knowledge: Managers can easily monitor their organisation's sustainability performance in terms of CO_2e emissions, whilst operationalising for economic growth. As an outcome, we advance theory on the tension between unsustainable consumption on the one hand, and the limited amount of CO_2e emissions that constitute a 'safe operating space' (Rockström et al. 2009) on the other, by moving beyond eco-efficiency per se.

After discussing the theoretical background to our research question, including the value-based approach we take towards CO_2e emissions, we unpack our time-efficiency indicator. In stating the specific calculations to be undertaken by users, we intimate how it can be used by managers to (a) assess the extent to which their organisation utilises its CO_2e emissions efficiently—both currently and historically to enable trend-based insights—and (b) to aid decision-making on how their organisation can utilise CO_2e emissions in the future to contribute towards NDC targets of reduction with greater impact. We then apply our indicator to a cluster of firms as a worked example of the calculations to illustrate the tool's application, but which also demonstrates its potential usefulness to policymakers working at the macrolevel. We outline the latter in our discussion, where we primarily discuss our contributions to theory as well as practice.

1 | Growth, Sufficiency and Eco-Efficiency

Some evidence suggests that economic growth might be desirable in that it can positively impact some societal problems such as unemployment and poverty (e.g., Ball et al. 2017; Dollar and Kraay 2002; Ghura et al. 2006). As an almost unchallenged norm amongst most governments and industries, strategies for growth typically manifest in an array of policy-based measures (e.g., Tanchev and Mose 2023) and are encouraged by global bodies such as the United Nations (2015), as plainly expressed by Goal 8 of the UN's Sustainable Development Goals, 'Promoting sustained economic growth, productive employment and decent work for all is essential for a sustainable future' (UN 2025). Synergetic-to-macroeconomic 'push' drivers are those that stem from a rising demand amongst consumers for an increasing array of products and services, with industry playing its part in terms of supply. In other words, pragmatically speaking, 'the core strategic goal of all economies and many businesses continues to be the pursuit of ongoing economic growth' (Edwards 2021, 3079), as well being reflective of consumption trends.

At the same time, some sustainability scholars have joined those from economics and political domains (e.g., Cazes et al. 2011; Ravallion 1997) to argue that although growth is the norm for many actors, it is not necessarily desirable. Some researchers, for example, argue that there is a need for sufficiency

(Jungell-Michelsson and Heikkurinen 2022; Princen 2005), a somewhat umbrella term (Figge et al. 2023) that describes a voluntary reduction in consumption with the aim of alleviating environmental pressures (Alcott 2008), and which includes related but nuanced ideas of degrowth (Buch-Hansen and Nesterova 2023; Kallis 2012; Kallis et al. 2018; Martínez-Alier et al. 2010; Polewsky et al. 2024), green-growth (Tilsted et al. 2021), zero-growth (Barrett 2018) and others (van den Bergh 2011).

Although seemingly attractive as a potential solution for some environmental based problems in isolation (e.g., unsustainable resource use), a whole system perspective suggests that sufficiency—and degrowth in particular—might be ethically problematic. Despite approaches that purposefully accommodate human well-being (e.g., Buch-Hansen and Nesterova 2023; Roy 2020) and socioecological wellbeing (Luzzini et al. 2024), decreasing production and consumption can be detrimental to economically disadvantaged populations. If economic growth reduces poverty (e.g., Ghura et al. 2006; Tanchev and Mose 2023), then without minimum income schemes (e.g., Alexander 2014) or caps on wealth (Buch-Hansen and Koch 2019)—which are themselves not without their challenges (Bastani and Waldenström 2023; Brülhart et al. 2022; Daruich and Fernández 2024; Jaimovich et al. 2024)—sufficiency-based strategies might encourage the opposite effect; that is, the world's poorest populations could well remain poor (Gräbner-Radkowitsch and Strunk 2023). Furthermore, sufficiency necessitates a shift in consumer behaviour (Kaufman 2023; Sheth et al. 2011). The intramicro mechanisms that underpin consumption behaviour are difficult to change, as for many individuals, the act of consuming involves positive neurological experiences (e.g., Behl et al. 2023; Lin et al. 2022) that pivot on 'immediate pleasure' (Quelch and Jocz 2007, 49). Thus, questions arise as to whether consumers are able to radically change their habits, even if they wanted.

These varied approaches to (post)growth highlight the difficult tension between consumption and the safe operating space (Rockström et al. 2009) for CO_2e emissions. On the one hand, it is unlikely that neither governments nor industry will cease to pursue growth nor will consumer demand dissipate (Cumming and von Cramon-Taubadel 2018). On the other hand, the evidence for there being limits to the amount of CO_2e emissions that can be safely emitted without the detrimental consequences of global warming, air pollution and so on seems increasingly irrefutable (Filonchyk et al. 2024).

Eco-efficiency (World Business Council for Sustainable Development [WBCSD] 1996, 2000) has been proposed as a solution to this tension. At its crux, it describes the 'ratio between an economic output (numerator) and a natural resource (e.g., copper, tungsten), as an ecological or environmental input (denominator): The greater the ratio, the greater the eco-efficiency' (Thorpe 2023). This overall logic has given rise to various organisational strategies, which can be collapsed into two broad types, differentiated on their underpinning logics. First, 'operational eco-efficiency' (Figge and Thorpe 2023) involves the generation of a greater return per unit of (natural) resource used. This describes a 'narrowing of resource flows', where organisations use less resources to make ostensibly the 'same' product (Bocken et al. 2016; Jørgensen et al. 2018)—thinner aluminium food cans, for example. In the context of CO_2e emissions, organisations reduce the amount of emissions it takes to produce the same number of units of product. A second strategy—and one that is increasingly combined with operational eco-efficiency (Bocken et al. 2016; Geissdoerfer et al. 2020)—concerns the circular economy (Pearce and Turner 1990), where both consumers and organisations partake in micro-based activities such as recycling and remanufacturing to support resource circularity as a macro-based phenomenon (Figge et al. 2023). Although less frequently applied to the context of CO_2e emissions, some early research proposed the viability of their recycling (e.g., Hashimoto et al. 1999)—although this is largely now confined to CO_2e intensive industries such as agriculture (Thomson et al. 2022), brewing (Merkouri et al. 2025) and petro-chemicals (Barecka et al. 2021). This failing is juxtaposed to shortcomings of an eco-efficiency approach per se. From an accounting perspective, improvements in efficiency represent a necessary condition for reconciling economy activity with environmental constraints—and it is for this reason that we include eco-efficiency as a partial logic to our indicator in this paper. Yet substantial research suggests that eco-efficiency alone cannot be enough to reduce CO_2e emissions in absolute terms to within acceptable levels. Rebound effects in the circular economy (e.g., Figge and Thorpe 2019; Zink and Geyer 2017) illustrate the point: Increasing eco-efficiency often drives greater consumption of new products, the production of which means additional CO_2e emissions. Thus, it seems likely that limits on consumption will be needed as an alternative or additional measure, as many postgrowth perspectives argue, if the planet is to avoid consumer demand offsetting the environmental gains made via eco-efficiency measures. It is not the purpose of our paper to align our argument to one growth or postgrowth perspective or another, but we do acknowledge there are partial contributions to be made from both eco-efficiency and the overall idea of reducing consumption in some way.

2 | Time

Some early work that explored temporal structuring in firms (Orlikowski and Yates 2002) followed initial conceptualisations of 'time' as a research lens for organisational scholars (e.g., Ancona et al. 2001). More recently, subsequent work has explored the relationship between time and business sustainability (Bansal and Knox-Hayes 2013) and, more specifically, how temporal perspectives shape organisational responses to climate change (e.g., Bansal and DesJardine 2014; Lê 2013; Mazutis et al. 2020; Nyberg et al. 2022; Ramus et al. 2021; Reinecke and Ansari 2015; Slawinski and Bansal 2012; Slawinski et al. 2017). However, much less attention has been paid to how time becomes, or can become, embedded in organisational-level indicators and performance assessment practices. One partial exception can be found from Figge et al. (2018) who argued that simply using products (e.g., cell phones)—and by default, their contained natural resources (e.g., gold)—for longer might enhance the effectiveness of resource circularity for a more sustainable use of resources. Through a worked example of cell phones, they illustrate the synergy between longevity and circularity by describing how loops of resource use can be 'slowed' by lengthening the time taken for the resource to pass through one cycle of use, before entering a second cycle of reuse, and so on. Although the authors did not discuss how longevity or time might be applied to the context of CO_2e emissions, the principle is arguably the same: The same amount of CO_2e is 'used' as a resource for longer periods of time.

The problem is that Figge et al. (2018) use resource circularity as a starting point to which they 'add' the idea of longevity (or 'time'). The result is that although their conceptual article is somewhat theoretically rich, it loses value in its developmental potential as a practical tool that nonspecialist managers can use: By starting with the circular economy, Figge et al. (2018) build in more complexity, rather than simplifying an already complicated system from a nonspecialist perspective. We argue that a more user-friendly tool for practitioners from the theoretical framework they propose might have been procured if (1) the focus was on the straightforward core assumption of eco-efficiency per se, that is, that economic growth is desirable, rather than on one of its more complex related frameworks, that is, the circular economy, and (2) the starting point had been longevity.

A further source of inspiration for the development of longevity-based tools for practitioner use can be found in the various social communication tools and outreach initiatives that have been developed for a public audience (e.g., Kitzes et al. 2009; Lee et al. 2021). These usually involve asking participants online to complete a series of questions, from which the output is a personalised 'eco-footprint' (Kitzes et al. 2009; Rees 2018), which is then communicated via a specific date: a 'tipping point' that represents when in the calendar year the participating individual stops living sustainably—in much the same way as Lee et al. (2021) illustrated in their calculations for Taiwan's overshoot day, as above.

The most well known of these public facing tools is Earth Overshoot Day (Lin et al. 2025; Wackernagel et al. 2002; Wackernagel and Lin 2024a, 2024b). Although methodologies differ (Ahsan 2023), at its crux Earth Overshoot states, the particular day in the previous 365 days where the planet becomes unable to regenerate its resources faster than they are used. Put differently, the amount of resources used on Earth up until this day (calculated from day one) is within the boundaries of a safe operating space (Rockström et al. 2009). Resources used after this date, that is, for the remainder of the 365 days, reflect unsustainable consumption—again, as illustrated in principle by Lee et al. (2021).

In terms of CO_2e emissions in particular, the concept of an overshoot day is intuitive: After a certain date, Earth has emitted as much CO_2e that is permitted to remain within a safe operating space. This is tangibly illustrated in the Global Footprint Network (2025) which produces a 'footprint calculator' (e.g., Lin et al. 2018)—a similar social communication tool to Earth Overshoot but within the specific context of CO_2e emissions. In the former, each individual calculates their carbon footprint by answering questions presented by the tool on, for example, the amount of meat, dairy and processed food they consume; the type of house they live in; how much energy they use; and their travel habits. Their personal overshoot day for CO_2e is calculated as a specific date in the calendar year. When presented like this, CO_2e emissions become something that is 'over here' (Ergene et al. 2021; Good and Thorpe 2020; Nadegger 2023), 'connected', personalised and relevant to individual actors, illustrating the capacity of a time-based logic to make CO_2e emissions meaningful to nonspecialists—something with which purely eco-efficiency based approaches, and particularly circular economy based initiatives, have arguably struggled.

Yet time-based approaches are also not without their challenges in practice. Whilst giving clarity at the individual level, such tools fail to reveal the reasons behind *why* each individual actor might be living (un)sustainably. It is assumed that an overshoot date of 31 December is reflective of a lifestyle that is optimised for sustainability, that is, reflective of lifestyle choices to limit the extent of air travel, meat consumption, energy usage and so on. However, life circumstances that revolve around poverty might also produce the same desirable overshoot date: Air travel and dietary habits are frequently influenced by available disposable income, as is the amount of energy consumed. Put provocatively, Earth Overshoot Day and the footprint calculator from the Global Footprint Network make no distinction as to whether a seemingly desirable overshoot day is the result of proactively sustainable choices—made possible by comparative affluence—or the result of poverty that forces individuals into consuming less.

Applied to an organisational context, the principle is the same. By only focusing on time and sidelining the importance of efficiency, it may mean that CO_2e emissions decrease, but at the detriment to the positive benefits for society derived from economic growth: Again, put provocatively—and as a conditional analytical argument rather than an empirical prediction—although CO_2e emissions improve, they are likely to do so by maintaining social inequalities.

Thus, we now propose our own metric that combines both longevity and efficiency, in response to our research question: *How can a time-based approach to address CO_2e emissions also accommodate the production of goods and services?*

3 | A Time-Efficiency Indicator for Organisations

Our proposed indicator enables each organisation—regardless of size, geographical location, industry or any other characteristic—to calculate its sustainability performance in terms of its CO_2e emissions and to express their performance in terms of time. In doing so, individual organisations can accurately assess whether they are on track to meet national or regional-based targets for CO_2e emissions in the future, such as those relating to 2030, as per the Paris Agreement (UNCC 2025), as well as GDP targets, and garner quantifiable insights into what operational adjustments, if any, they need to make.

As before, we frame CO_2e emissions as a resource (Ayres and Kneese 1969), with an economic value attached to them as they contribute to the production of consumer products and services, with two clarifications. First, a value-based approach does not imply per se that CO_2e emissions should be commodified. Second, its base logic might erroneously imply legitimacy for increasing CO_2e emissions, that is, that organisations are morally approved to generate a greater degree of emissions if it means they produce more value—potentially producing a rebound effect, as before (Jevons 1866).

In terms of the tool itself, three points should be noted. First, it is not the purpose of the indicator to attribute any proportional moral responsibility for emissions, even though the use of national targets might imply as such. However, their use is necessary to enable organisations to benchmark their performance on their emissions against other organisations, sequentially enabling some perhaps much needed operational and strategic change, as before. In principle—and perhaps in the future—targets relating to cities or smaller regions within a country might be used, but in their current absence, it is only national targets that can enable organisational benchmarking. Second, we exclude Scope 3 emissions within our tool's calculations. This means that some organisations that might be expected to be high polluters seem 'greener' than they actually are. Although oil and gas firms, for example, score poorly on their Scope 1 emissions that relate to extraction, their Scope 3 emissions, relating to the use of fuel by consumers, are also very poor, and yet the latter cannot be taken into account. The rationale for their exclusion—regardless of the organisation or sector—pivots on the difficulties in capturing data using a single methodology that refer to all upstream and downstream emissions in the value chains of all firms. Third, we consider value distribution across multiple stakeholders, that is, beyond the purely shareholder-centric perspective commonly found amongst financial management research. However, it is outside the scope of the tool to capture all possible conceptions of value, for example, those that concern nonmonetized social and community based impacts.

Completing a simple set of calculations for each (and any) 365-day period (e.g., 1 January 2025 to 31 December 2025), within the scope of a single organisation, produces a date that indicates the point in time that it 'used' its 'share' of CO_2e emissions that are permitted within a safe operating space—essentially an 'overshoot date'. Crucially, these calculations accommodate the extent to which the organisation has or is 'using' CO_2e efficiently. In terms of robustness, it should be noted that specified 'overshoot dates' are sensitive to changes in GDP projections and/or emissions targets. However, when the tool is used for cross-organisation comparisons, this has no effect as long as the same targets are used in the calculations.

3.1 | Calculations

As a five-step process, the calculations to determine an individual organisation's overshoot date are as follows:

Step 1: We calculate the eco-efficiency of the organisation. To do so, we find the gross value added created by the organisation by adding its earnings before interest, tax, depreciation and amortisation (EBITDA) with its personnel expenses. This is a standard process used to calculate the value added created at the organisational level and is more appropriate than using 'revenue' or 'operating profit' (EBIT): Our choice of EBITDA and personnel costs captures the value created by the company. Revenue would include the value created outside the company by the company's suppliers and thus overestimate the value created by the company. Any profit figure such as operating profit or net profit would ignore the employee's share of value creation. The direct way of calculating value creation of companies by deducting the cost of all supplies from revenue is impossible from an external perspective due to the lack of an aggregated figure for the cost of supplies. We therefore approximate the value created by the company by adding EBITDA and personnel costs.

We divide the sum of EBITDA and personnel costs by the organisation's CO_2e output to find 'A'. 'A' corresponds to the eco-efficiency of the organisation.

$$\frac{EBITDA + personnel\ expenses}{\mathrm{CO_2e}} = \mathrm{A}$$

Step 2: This step determines the benchmark to which we compare the organisation's output. This could follow different logics. In theory, the global target for emissions could be used, for example. Here, we use national targets, although it should be noted that these may or may not reflect the scientific consensus of what may be 'enough'. We take the GDP of any one particular year of the same country in which the organisation is based. (The year selected must be the same as the year in Step 1.) To produce 'B', we then divide this figure by the same country's CO_2e emissions for that year. Alternatively, we can relate expected GDP for a future year to the country's CO_2e target emissions for that year. This choice depends on the aim. The former enables users to understand the historical performance of the organisation. The latter enables users to understand whether the organisation is on track to meet the future national targets for the reduction of CO_2e emissions. Most countries have targets for both GDP and CO_2e that go to 2030 (and frequently beyond), so it is useful to use 2030 as a benchmark to determine the likelihood of the organisation reaching the national benchmark in the future.

$$\frac{GDP\ of\ country\ X}{\mathrm{CO_2e\ of\ country\ X}} = B$$

Step 3: We divide the eco-efficiency of the organisation by the eco-efficiency of the national benchmark, as follows:

$$\frac{A}{\boldsymbol{B}} = C$$

Step 4: We calculate the length of time (measured in days) that the organisation takes to reach its overshoot day. To do so, we multiply C by 365.

$$C \times 365 = D$$

Step 5: Finally, we add D to 1 January to find the organisation's overshoot day.

3.2 | Illustrative Example of Application

A worked example, in which we focus on the United Kingdom and firms listed on the FTSE 100 index, illustrates how our indicator might work in practice. We have chosen the United

Kingdom as an example of a country that strongly contributes to sustainability orientated debates and governance at an international level, which also has a strong track record of implementing national policies that support environmental protection (e.g., Department for Environment, Food & Rural Affairs 2020a, 2020b; Ministry of Housing, Communities and Local Government 2023; UK Parliament 2021). As one of the world's leading stock exchange indices, the FTSE 100 index consists of companies that tend to have a comparatively strong interest in environmental issues, are globally active and are spread across a diverse set of sectors (Morris and Guenther 2024). However, we again emphasise that our indicator can be applied in the context of any country, as well as to any index, sector or other way of grouping organisations with some sort of commonality (e.g., the third sector).

In compiling our example, we used the LSEG (formally Refinitiv) database to access financial data, with the FTSE 100 as our investment universe. We compiled data for the last 3 years for each firm (2022–2024 inclusive). Where available, we accessed financial data (EBIT, depreciation, amortisation and personnel costs) and environmental data (total CO_2e emissions—Scopes 1 and 2) needed for calculations. As LSEG does not indicate the share of CO_2e and financial data that are specific to UK operations, we assumed that their group-wide operations are representative of their domestic operations. We chose only to calculate the previous 3 years: Lock-down from coronavirus in the United Kingdom ended in March 2021 (Institute for Government Analysis 2025), with 2022 being the first full calendar year that all sectors returned to prepandemic production.

When calculating the benchmark—*Step 2* of the previous section—we used two other sources that state verified targets for 2030. To obtain the UK target for (real) GDP for up to 2030, we used the World Economic Outlook database of the International Monetary Fund (IMF) (2025a). This database contains historical GDP growth rates but also estimated targets until 2030—with 2022 as the base year, with adjustments made to nullify the effects of inflation, as per the methodology of the IMF (2025b). Statista (2025) provided us with the most recent published (real) GDP output of the United Kingdom, which was just above GBP 2.78 trillion in 2024.

To obtain CO_2e emission targets for 2030—again, to calculate the benchmark in Step 2—we accessed verified statements from the UK government showing the CO_2e emission reduction targets for the United Kingdom (Department for Energy Security and Net Zero [DESNZ] 2025). From this, we used the figure of a 68% reduction of CO_2e emissions by UK companies compared to emissions in 1990 (the base date used for CO_2e emission reduction targets). We used 1990 CO_2e emissions for the United Kingdom to calculate 2030 targeted emissions stated by DESNZ (2025).

We then cleaned the data. We excluded firms for which some or all of the data were not available for at least one of the 3 years we assessed, as well as firms that did not have data for 2024. On this basis, we eliminated 22 firms. In total, we used data for 78 firms out of the FTSE 100 for our example.

We then followed the process as indicated in the previous section. Table 1 reflects the output of our indicator in this one context. Although our example of the FTSE 100 is purely illustrative, we reordered the firms on the extent to which they are 'unsustainable' (as deemed by our tool) for 2024—the most 'unsustainable' first—purely for making comparisons easier between firms—perhaps in much the same way that firm managers might use the tool to benchmark against other similar firms. For example, the 'overshoot day' for Easyjet PLC is 8 January. In other words, if Easyjet continues to emit CO_2e in 2030 at the same level as it did in 2024, whilst contributing the same amount of gross value added, it will contribute to the United Kingdom failing to meet its combined GDP and CO_2e emission targets after 8 January. Put differently, the CO_2e emitted after this date is not in line with the agreed target of limiting global warming to 1.5°C. We can also see that Easyjet is less sustainable than International Consolidated Airlines Group (ICAG), for example, which had its overshoot day 2 days later. As before, the purpose of the tool—and our illustrative example—is not to attribute moral responsibility but rather to show how one firm can benchmark its results comparatively.

Although this overview of the FTSE 100 is interesting per se—with implications for policymakers that we discuss in the next section—it also demonstrates our indicator's usefulness for individual organisations in two ways. First, as above, managers can assess whether their organisation is becoming more or less likely over time to meet national 2030 targets (or others). Our illustrative example shows how managers at Airtel Africa PLC, for instance, can garner insight into the organisation's progress: The firm shows a marked improvement over 3 years, with 2024 being the first year that they appear to be operating within the national 2030 emissions target. Second, it allows for organisations to compare themselves to each other, irrespective of company size. This might be especially useful within the same industry, for strategic purposes, as we discuss below.

4 | Discussion

Our conceptual paper set out to explore the following research question: *How can a time-based approach to address CO_2e emissions also accommodate the production of goods and services?* In response, we combined time- and efficiency-based logics to offer an indicator that mirrors the accessibility of several time-based initiatives (e.g., the Global Footprint Network) in the public domain, which also accommodates production and growth. After calculations, the output is a specific calendar date—a 'tipping point'—that reflects when an organisation's CO_2e emissions becomes unsustainable, which we demonstrated with a worked example of organisations listed on the FTSE 100.

4.1 | Contribution to Theory

We advance current understanding of how society can encourage organisations to lower their CO_2e emissions by extending current theory. Succinctly, we move beyond an eco-efficiency logic that drives the majority of theoretical frameworks and indicators pertaining to CO_2e emissions, by assimilating a time-based approach that at once enriches and simplifies the theoretical framing of our indicator. We extend theory by nullifying the trade-offs of each approach when they are

TABLE 1 | FTSE 100 firms ordered by their overshoot day.

Company name	Overshoot date FY0: 2024	% of FTSE total CO_2e	Overshoot date FY1: 2023	Overshoot date FY2: 2022
Easyjet PLC	2024/1/8	4	2023/1/7	2022/1/6
International Consolidated Airlines Group SA	2024/1/10	11	2023/1/11	2022/1/15
Glencore PLC	2024/1/15	12	2023/1/16	2022/1/27
SSE PLC	2024/1/20	2	2023/1/15	2022/1/15
Anglo American PLC	2024/1/20	5	2023/1/21	2022/1/27
Mondi PLC	2024/1/21	1	2023/1/20	2022/1/28
Rio Tinto PLC	2024/1/23	11	2023/1/22	2022/1/24
InterContinental Hotels Group PLC	2024/1/25	1	2023/1/24	2022/1/24
Shell PLC	2024/1/26	25	2023/1/26	2022/2/1
BP PLC	2024/1/27	15	2023/1/30	2022/2/11
National Grid PLC	2024/2/2	3	2023/1/31	2022/1/25
Fresnillo PLC	2024/2/2	<1	2023/1/17	2022/1/19
Antofagasta PLC	2024/2/5	1	2023/2/2	2022/1/31
Endeavour Mining plc	2024/2/9	<1	2023/1/31	2022/1/31
Centrica PLC	2024/2/11	1	2023/3/3	2022/3/4
Associated British Foods PLC	2024/2/20	1	2023/2/21	2022/2/13
Severn Trent PLC	2024/3/12	<1	2023/3/3	2022/2/24
Coca Cola HBC AG	2024/3/22	<1	2023/3/25	2022/3/23
United Utilities Group PLC	2024/4/9	<1	2023/4/14	2022/4/3
Croda International PLC	2024/4/29	<1	2023/3/31	2022/5/9
Vodafone Group PLC	2024/5/24	1	2023/6/4	2022/7/9
Weir Group PLC	2024/6/22	<1	2023/6/20	2022/5/26
Marks and Spencer Group PLC	2024/7/24	<1	2023/7/6	2022/6/28
J Sainsbury PLC	2024/7/26	<1	2023/7/21	2022/6/22
Hikma Pharmaceuticals PLC	2024/8/4	<1	2023/7/23	2022/7/23
Unilever PLC	2024/8/8	1	2023/7/25	2022/7/16
Tesco PLC	2024/8/13	1	2023/7/15	2022/6/20
Diageo PLC	2024/9/20	<1	2023/9/23	2022/9/15
Rentokil Initial PLC	2024/10/5	<1	2023/9/27	2022/10/12
Intertek Group PLC	2024/10/26	<1	2023/10/17	2022/10/9
Whitbread PLC	2024/11/5	<1	2023/10/17	2022/10/6
Ashtead Group PLC	2024/11/10	<1	2023/12/31	2023/1/6
Airtel Africa PLC	2024/12/22	<1	2024/3/15	2023/4/5
Melrose Industries PLC	2025/1/27	<1	2023/9/12	2022/4/1
Kingfisher PLC	2025/3/7	<1	2023/12/13	2022/11/7
BT Group PLC	2025/3/8	<1	2024/2/15	2023/2/12
Reckitt Benckiser Group PLC	2025/3/9	<1	2024/3/6	2023/2/3
Bunzl plc	2025/4/27	<1	2024/4/1	2023/2/20

considered separately: As we have discussed, intuitive, time-based approaches do not take into account an efficiency-based logic and thus negate the positive effects that efficiency—and ultimately growth—can generate for human development (e.g., Ball et al. 2017; Ghura et al. 2006; Dollar and Kraay 2002; Tanchev and Mose 2023). Similarly, although eco-efficiency approaches accommodate the desirability of growth, they are often sidelined in practice owing, at least partially, to their complexity. In essence, our novel theoretical framework and resulting indicator enable the discourse to move from an 'either/or' dynamic between the societal benefits of eco-efficiency on the one hand and simplicity on the other, to a 'with/and' perspective.

Although it might be argued that the complexity of eco-efficiency does not or should not undermine its theoretical value per se, such is the urgency and crucial nature of CO_2e emissions for the planet that we argue the ability to generate real impact for practice from theory is paramount for its utility. Thus, our contribution extends from a novel theoretical framework to the time-based indicator that accommodates eco-efficiency at its core: As an output, our indicator illustrates a more holistic theoretical basis of measuring and monitoring CO_2e emissions at the organisational level.

4.2 | Contribution to Practise

Although the logic of our tool could accommodate the use of GDP and emissions targets pertaining to cities or perhaps smaller regions within countries, owing to their absence, the use of national targets is likely. However, managers should note that national targets do not necessarily correspond with expectations derived from the global carbon budget.

Our main contribution to practise concerns the novel indicator that encompasses a straightforward, intuitive and user-friendly process. Its simplicity is underpinned by basic accounting principles and easily accessible organisational data. Furthermore, the indicator can be used by all types of organisations—as manufacturers or service providers—regardless of sector, geographical location, size, turnover, and so on, providing that national targets of GDP and CO_2e emissions can be reliably sourced.

As before, the purpose of our tool is to help organisations elicit strategic and operational changes through benchmarking means—rather than implying any proportional responsibility for emission outputs. Several user profiles are evident. First, are managers wanting to track their organisations performance on CO_2e usage historically that can lead to reliable future trajectories that they can compare to national targets of CO_2e reduction by, for example, 2030 or 2035. Simply put, it enables each organisation to answer the question, *in the scope of the current activities and initiatives* (if applicable) *to reduce our organisation's emissions, are we on track to meet national targets to reduce CO_2e by* (for example) *2030, while contributing to expected GDP growth?* The caveat here is that adjustments will need to be made if national GDP and/or emissions targets change to ensure the validity of year-on-year comparisons. Nevertheless, our tool enables managers to make better informed decisions on capital allocation and where in the organisation investments might be made to reduce their CO_2e, even to the point of springboarding decisions, actions and changes to move their organisation to net-zero emissions.

A second user profile are managers who want to use our indicator as a strategic tool. Applying the calculations to their own organisation and others enables managers to compare emission trends between their own first and those of their direct competitors, best in field, and so on. Again, this is made possible by our indicator's use of easily accessible, often publicly available data. As society is increasingly scrutinising industry over the accountability of CO_2e emissions, there is every indication that 'performance' in this sense will become increasingly important to stakeholders (Adetutu et al. 2024; Liu et al. 2023). A third profile concerns managers that also want to use the indicator as a strategic tool, but who are also driven, at least in part, by ethical drivers to reduce their organisations' CO_2e emissions. Our indicator can aid, for example, scenario planning around CO_2e emissions with other macrolevel phenomenon with specific industry factors.

4.3 | Implications for Policymakers and Society at Large

As one of the primary emitters of CO_2e, industry arguably needs to do more in helping to address global emissions. Yet, as a natural world entity, it is perhaps understandable for some managers to perceive CO_2e emissions—and global targets for their reduction—as something abstract, disconnected and 'over there' (Ergene et al. 2021; Good and Thorpe 2020; Nadegger 2023). We argue that the accessibility and intuitiveness of our indicator can help to reframe CO_2e emissions as something 'over here', that is, as more relevant and connected to firms, and might propel a greater sense of urgency and motivation amongst managers to act.

One user profile amongst policymaking pertains to those who have responsibility for operationalising such action at the national level, in accordance with the Paris Agreement (United Nations 2025), but who favour approaches that foreground, or at least accommodate, the positive spillover effects of growth (Ghura et al. 2006; Tanchev and Mose 2023). As a further user profile, policymakers can use the indicator to generate specific insights into the industrial landscape per se. Calculating the CO_2e emissions en masse of, for example, geographically colocated organisations or specific industry-based groups and so on, enables a rich more nuanced understanding of the differentiated progress being made within industry. This could potentially lead to the development of more targeted—and thus more effective—policy interventions. Our own worked example of the FTSE 100 illustrates. By rearranging the participant firms in order of their 'tipping points', that is, the date in the calendar year that they seize emitting CO_2e that is within a safe operating space, we can see that (1) five firms—all having a tipping point in January—account for 74% of the total CO_2e emissions (of all firms in the FTSE 100 for which data is available), (2) 11 firms—all but one having a tipping point in January—account for 90% of CO_2e emissions and (3) 61 firms out of our sample are responsible for less than 5% of CO_2e emissions. To be clear, we are not suggesting a practice of 'naming and shaming' specific organisations, but this does illustrate an example of the useful insights our indicator can generate at the policy level. For instance, certain manufacturing-based industries—but also the hotel and leisure industry—are disproportionately contributing to the problem of CO_2e emissions, suggesting that little progress will be made (in the context of the United Kingdom) if policymakers do not develop a more targeted strategy. In this sense, our tool supports diagnostic targeting, rather than uniform regulatory control.

4.4 | Limitations and Further Research

The role of Scope 3 emissions is increasingly recognised as a critical component of corporate contributions to climate change. However, the measurement and reporting of Scope 3 emissions remain in its infancy (Hettler and Graf-Vlachy 2024), and estimates are often incomplete, with a high margin of error, or methodologically inconsistent across firms and sectors (Vieira et al. 2024). Our indicator does not take into account Scope 3 emissions. Our decision for their exclusion was grounded in conceptual coherence: For the indicator to retain validity, the measure of value creation (here, gross value added) must correspond to the emissions directly related to value generation. This correspondence exists clearly for Scopes 1 and 2 emissions, but not for Scope 3. Including Scope 3 would therefore risk misaligning the 'value' produced by an organisation and the emissions used to produce that value.

However, the exclusion of Scope 3 emissions necessarily introduces a limitation. Organisations are embedded in complex webs of interdependence, in which the outputs of highly polluting firms—such as Shell, Rio Tinto or BP—form the inputs for other, seemingly less polluting firms. Any firm-level assessment that focuses only on direct emissions may therefore understate the broader systemic reliance of organisations on carbon-intensive supply chains. As with all firm-specific sustainability indicators, the results of our time-efficiency metric should therefore be interpreted with caution. Overshoot dates reflect an organisation's direct eco-efficiency relative to national benchmarks, but they do not capture the full upstream and downstream emissions that contribute to its value creation.

With the caveat of the exclusion of Scope 3 emissions, we have argued for the usefulness of our indicator, as above. In principle, managers may use the tool to explore their organisation's use of other resources, which are fundamental to their products and services but which have implications for sustainability. Rare earth elements (REE), for example, used in technology orientated products (Binnemans et al. 2021) could replace CO_2e emissions in our indicator's calculations. The challenge, however, comes from the lack of national targets for alternative resources to CO_2e emissions. Further research might explore how the calculations might be adapted to accommodate such limitations.

4.5 | Concluding Comments

The juxtaposition between efficiency-based perspectives and time-based paradigms has been one of 'either/or' with trade-offs being inevitable. Our tool extends current theory by shifting to a 'with/and' framing, where through an amalgamation of the two approaches such trade-offs are largely negated, and propelling 'time' into having a more prominent role.

It is important however to point out several boundary conditions, especially relating to our subsequent tool. First, although we conceptualise value creation as a jointly generated and distributed outcome amongst key organisational stakeholders who collectively contribute to, and are affected by, the organisational activities, we stop short of attempting to capture conceptualisations of value that revolve around social and community impacts: These are—in its current form—outside the scope of our tool. Second, our tool does not claim to capture all emissions for comparative purposes: Managers can only carry out inter-organisational benchmarking on the basis of Scopes 1 and 2 emissions. The omission of Scope 3 is an important necessity as the data used must be consistently reliable to elicit meaningful interorganisational comparisons. Nevertheless, the tool can also be used additionally by managers to track the progress of their own organisations over time, perhaps aiding decisions that concern capital investments, personnel deployment and other activities, for example, to move towards decarbonisation.

It is not the purpose of our tool to allocate the moral responsibility across firms via benchmarking. However, policymakers will find the tool useful for better understanding the CO_2e emission 'landscape'. In moving the conversation forward, we hope that other scholars, as well as those engaged in practice, will continue to pay closer attention to the contribution that longevity can make towards a more sustainable planet and to further develop theory and tools accordingly.

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