

Perspective

Do's and Don'ts in Climate Impact Assessment of University Campuses: Towards Responsible, Transparent and Comprehensive Reporting ‡

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‡ Part III of the series: Carbon footprinting of universities worldwide.

Abstract: With the commitment of more and more universities to decrease greenhouse gas emissions, standardizing the modeling is now becoming urgent. To date, published climate-relevant emissions can be based on completely different and incomparable accounting methods, as shown with results between 6 and 2696 t CO₂e for the use phase of the same campus. This article aims to identify, compare, and evaluate the different modeling approaches behind this. For this purpose, this article proposes basic attributes of emissions modeling and reporting. Of the three established approaches to emissions accounting, sector logic (territorial carbon accounting) produces the lowest figures. Reporting in accordance with the greenhouse gas protocol, which has become established worldwide, can also shift the responsibility outside the institutional consumer. Life-cycle assessment, instead, essentially includes provision costs triggered by the consumer. The different modeling approaches also overlap with different coverage of emission sources, for which a standard set is being proposed. Such emissions modeling should finally lead to the determination of university-specific climate performances, i.e., the CO₂e emissions per capita and per m² of gross floor area. Infrastructure and procurement expenses must be recorded in addition and converted to an annual average.

Keywords: GHG emissions; universities; higher education institutions; carbon footprinting; Umwelt Campus Birkenfeld; greenhouse gas protocol; life-cycle assessment (LCA); embodied emissions; climate performance; sustainable university; territorial carbon accounting; sector logic



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1. Introduction

European universities began to address sustainability issues at an early stage: The COPERNICUS University Charter for Sustainable Development from 1993 is seen as “a response to the Earth Summit in Rio de Janeiro in 1992 and marked a breakthrough in raising awareness at European universities” [1]. The development of this COPERNICUS University Charter now dates back over 30 years. Although the United Nations Framework Convention on Climate Change (UNFCCC) was established at the same time in 1992 [2], there was apparently little interest only at universities in what is perhaps the most important sustainability issue: climate change. There were exceptions, however: ETH Zurich, for example, published its first CO₂ emissions report already back in 1990 [3]. It is not by chance that this university revealed the best CO₂e performance in a recent international comparison [3]. The conclusion is that reducing CO₂e emissions is not akin to a sprint but to a marathon for a university. This is also a great danger when it comes to greenhouse gas (GHG) neutrality targets set for the years 2045 (Germany), 2050 (European Union), 2060 (China), or 2070 (India), respectively, to which universities in the respective countries are affiliated usually. These annual figures are projected to be reached in almost a generation (30 years) to almost half a century (India) in the future. A comparison with the situation in the 1990s, which was also characterized by new beginnings, suggests that, in view of such far-off goals, many players are probably still planning to “wait and see”.

However, the interest in the modeling of climate-relevant emissions from universities worldwide has been steadily increasing recently: Several statistical bibliometric reviews on university carbon footprinting published in recent years exhibited that before the period of 2013–2017, there were very few scientific publications on this topic only, while since 2019/2020 there is a steep popularity increase [4–7]. There are some international university sustainability forums today addressing GHG emissions, among other factors, which comprise mostly universities from North America and Europe, but fewer from the global south [4].

Additionally, the past 10 years have also been characterized by UN-level institutional support: The UN Sustainable Development Solutions Network (SDSN) works together with universities worldwide to strengthen sustainable development [8]; SDSN has issued a practical guide for universities and colleges to accelerate climate action on the way to net zero campuses [9]. By sustaining their campuses, universities support the implementation of the 17 central sustainable development goals (SDGs), in particular the SDGs 4,9,16, and 17 (reviewed by [10]). University carbon footprint is directly supporting SDG 13 (climate action), and indirectly, by saving resources and reducing emissions, the SDGs 14 and 15 (life below water, life on land), SDG 6 (clean water), and by targeting a sustainable infrastructure, SDG 11 (sustainable cities). Of course, the sustainable economy SDGs (8,9,12) are addressed as well. Concluding, university carbon footprinting is a sustainability action in a holistic sense.

Universities in the USA, the UK, and Australia have played a pioneering role in publishing emission inventories (reviewed in [3]). In the UK, a standardized accounting framework was adopted as early as 2012 [11,12]. A nationwide overview is now even available, according to which 537 institutions in the tertiary education sector were responsible for a total of 2.3% of the UK's CO₂e emissions in 2020/21 [13]. In Denmark, for example, higher education institutions have also agreed on standards for CO₂e accounting [14]. While in some European countries like Finland, almost all institutions report their emissions, a minority only had set emission reduction targets [15]. Germany has some catching up to do here. Initial projects in Germany are currently attempting to arrive at a standardized accounting framework (e.g., [16]).

Why is sustainability at universities so important, especially when crystallized in the goal of climate protection, and in this case, in the tangible amount of climate-relevant substance emitted in tons per year? First, there is the sheer size of this sector: around 17,000 institutions of higher education institutions (HEIs) worldwide serve and employ more than 207 million people [11], which currently correspond to around 2.5% of the world's population. In Germany, for example, 3.85% of the population studies and works at universities, while in the USA, 5.6% of the total population alone is enrolled at universities (reviewed in [3]). This is, therefore a relevant economic sector whose emissions should be known as precisely as possible in the interest of climate targets defined.

However, there is another factor that makes universities a place where sustainability and climate protection, in particular, must—finally—play a pioneering role: The higher education sector is the place where the experts for all disciplines are trained who will have to put into practice the climate-friendly and generally sustainable restructuring of the economy and society. In this context, it should be of concern that the proportion of compulsory sustainability topics, as addressed in classes taught in German mechanical engineering and business administration degree programs, makes up only 5–6% of those programs in total [17]. Beyond educating students, universities have a diverse impact on society and should, therefore, be pacesetters in sustainability [18].

The title of this article is based on universities being role models: responsible, transparent, and comprehensive determination and reporting of greenhouse gas inventories by universities should be encouraged and required (Table 1). Not only does UN Secretary-General Guterres call for “zero tolerance for greenwashing” in CO₂e accounting [19], but greenwashing would be particularly intolerable at universities because this is where students acquire the tools and the attitude they will apply later in their professional lives. If

science seeks truth, then universities also have an ethical responsibility to record their GHG emissions transparently, responsibly, and completely (Table 1).

Table 1. Perspective: suggested basic characteristics for reporting climate-relevant emissions from universities.

Basic Attributes of Emissions Modeling and Reporting	Explanation
responsibility	• Take responsibility for emissions caused in the supply chain; do not shift them to other sectors and countries • Set emission reduction targets • Carry out independent validation • Analyze and act in line with scientific findings
transparency	• Structure emission sources clearly, coherently, and in detail • Identify trends and dominating emission sources of the institution • Enable comparisons based on established climate performance indicators
Comprehensiveness	• Include provision and disposal of emissions • Include all significant emissions caused by the institution (mobility in particular) • Consider CO₂ equivalents • Consider the impacts of infrastructure and procurements over the life cycle; this way enables the development of a future low-emission university

This article is the 3rd part of a series. In the first part, use-phase GHG emissions from universities worldwide were examined, and a standardization was proposed [3]. In the second part, a complete climate impact assessment of two campuses, including embodied impacts, was reported for the first time [20].

In the third part of the series, the practice of university carbon footprinting, as it can currently be observed, is being analyzed and evaluated, and recommendations are made. In international practice, there are three main attempts at assessing GHG emissions on campuses: First, there is territorial carbon accounting (“sector logic”), an approach that views an (institutional) consumer as isolated from its economic and industrial environment, which minimizes responsibility for self-caused emissions. In contrast to the latter approach, life-cycle assessment (LCA) and the greenhouse gas protocol (GHGP) are considered methods of climate (or environmental) impact modeling [21]. In a review published by Paredes-Canencio et al. [22] covering 50 university carbon footprinting reports, the largest proportion (44%) reported following the GHGP, while the second largest group (22%) applied LCA approaches to report GHG emissions.

2. Materials, Methods, and Purpose of This Article

As a perspective on which this analysis is grounded, basic attributes of emissions modeling and reporting for HEIs are prefixed in Table 1 based on reviews published on university carbon footprinting [3–7,9–15,20,22–27]. Important obstacles in this context are outlined below when discussing the different accounting schemes and assessed with respect to the criteria shown in Table 1.

Among the approaches to measuring emissions, there is first a great inconsistency in the catalog of impacts considered on campuses. Following the terminology of LCA, these impacts make up the emissions inventory [28]. The basic requirement for emissions modeling is to draw up a complete inventory. Section 3.1 summarizes the different depths of analysis of the figures published so far and proposes the completion of the campus’ own impacts.

This contribution does not provide a comprehensive comparison of climate impact assessment methods. Instead, it focuses on the three main accounting schemes applied so far for balancing GHG emissions on campuses (Section 3.2). Above all, the application of sector logic (territorial carbon accounting) is tacitly assumed in HEI emission reports (e.g., [29]), which is why this approach is explicitly named and analyzed here. Because

LCA and sector logic are opposites in their approach, they will be contrasted with each other in the analysis (Section 3.2.1). The GHG modeling of electric cars and the concept of “zero-emission mobility” is used as an analogy to campus emissions modeling, based on research results on the LCA of electric cars on the one hand [30] and model calculations for zero-emission mobility on the other [31,32].

The third attempt to report GHG, the GHGP, differs as well from the two aforementioned, as it is operationally defined and designed primarily to simplify emissions counting for companies [33]. It will be evaluated separately in Section 3.2.2 here, following sector logic and LCA. The GHGP, however, has become established worldwide and is preferred by HEIs as well [22]. The origins of this method will be analyzed based on information provided by the author organizations [34–37].

GHG accounting is not an end to collecting data, but it is able to quantify the performance level of an institution, foster quality management, reduce emissions, and thus strengthen responsibility and transparency. Accordingly, comparative campus climate performance data are compiled and sorted based on reviews and institutional data [3,7,15,20,25,38–43]. Following this, a new quality rating is proposed (Section 3.3).

Finally, this article examines the future perspectives and the suitability of the various approaches to campus emissions modeling (Section 4).

3. Results and Discussion

3.1. Composition of GHG Emissions from Higher Education Institutions (HEIs)

In principle, the inventory of emissions consists of three parts. Figure 1 shows three parts of equal size, which shall hint at comparable importance but not quantitative equivalence. To date, universities have almost exclusively accounted for use-phase emissions (A and B in Figure 1). Reviewing the international scientific literature exhibits which impacts need to be covered essentially: These are emissions due to energy consumption, all mobility-related emissions (including student commuting), emissions due to the disposal of all waste (wastewater, solid waste), procurement of office supplies, as well as procured chemicals, gases and cleaning agents (A + B in Figure 1, [3]). This list is straightforward and logical in itself, as these are the expenses usually caused and controlled by the institution itself. For example, commuting mobility of employees and students is essential to be covered because its intensity is widely under the control of the university (e.g., by the degree of online teaching). However, as commuting takes place in the private sector, the corresponding figures are often unavailable to the university administration. Education institutions need to collect such data with the help of surveys by which the distribution of distances travelled is being studied and extrapolated.

Occasionally, studies record emissions caused by food provision in campus restaurants (e.g., [26]). However, as people also need to eat outside the university, this does not count as emissions caused by the university. It could, in turn, be a source of CO₂ credit: if, for example, a university operates a canteen with exclusively vegetarian meals offered, it may be argued that the statistical amount of meat consumed in the population will be decreased. Paredes-Canencio et al. [22] specify further use-phase emission sources, which were rarely covered by reports. Very few additional items of the campus inventory (e.g., electronic equipment) are being discussed in the literature [24]. On the other hand, obvious use-phase impacts are still being neglected by some HEIs in reporting [15].

Nevertheless, in an evaluation of the international data situation conducted a few years ago, it was not possible to identify 20 universities in whatever continents that had quantified the same emissions in their reports and were, therefore, directly comparable with each other [3]. For several universities, the mobility impacts of students had to be re-modeled based on standard assumptions, for example, in the case of ETH Zurich [3]. The magnitude of student mobility emissions can be easily and considerably influenced, for example, by introducing online teaching days, as experienced during the coronavirus period (e.g., [44]).

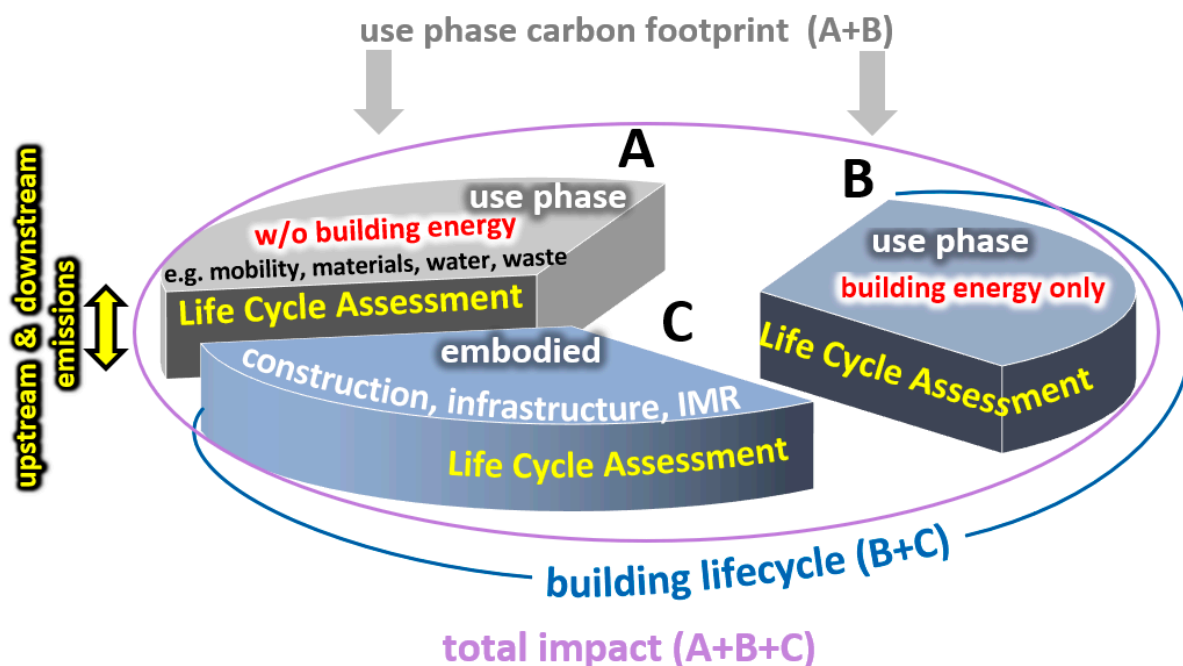


Figure 1. Composition of GHG emissions from Higher Education Institutions (according to [20]), supplemented by the temporal dimension of life-cycle assessment (LCA). IMR = inspection, maintenance, repair.

The data situation may have improved recently. In the preparation of this article, some universities have been identified that publish reports comprising the complete inventory of emissions as is being suggested here; for example, Tel Aviv University, Israel [38], Pusan University, Korea [25], and Victoria University Wellington, New Zealand [39], respectively.

The analysis of the university GHG emission structure revealed that the relative quantity of use-phase impacts varies greatly from place to place: energy consumption-related GHG emissions accounted for 9–77% of total emissions, while mobility-related emissions were responsible for 22–91% of the total emissions of 20 universities investigated [3]. In other words, each university is facing its own individual challenges when decreasing GHG emissions. At Umwelt Campus Birkenfeld, Germany, for example, the commuting emissions of the students make up 91%, while at ETH Zurich, the GHG emissions of business flights dominate [3]. At the University of Melbourne, 77% of the CO₂e emissions are due to electricity consumption [3].

Figure 2 is meant to further illustrate the inter-university comparability problems so far. Many universities solely document building energy consumption (Figure 2, box 1). Some consider parts of further use-phase emissions, like business vehicle fuel consumption, but do omit other use-phase impacts, like business travel and commuting (Figure 2, box 2). Essential impacts to cover within the use-phase emissions are shown in Figure 2 (box 3). Embodied impacts constitute another important component of thorough CO₂e reporting (Figure 2, box 4). However, the illustration in Figure 2 is still a simplification in the sense that all reporting schemes (Figure 2, boxes 1–4) can come with and without consideration of upstream and downstream emissions (provision impacts, shown in Figure 2, box 5) which are regularly covered by LCA, but excluded by sector logic and when reporting in accordance with the GHGP based on scopes 1 + 2 only (see below).

The consequences of such different approaches can be illustrated by data published on the carbon footprint of the Umwelt Campus Birkenfeld (Germany), a campus with 2450 students at the time of analysis: Its sustainability report mentions 6 tons of CO₂ emissions per year from business vehicles [29]. The report communicates that it wants to consider building energy emissions, accordingly, following a scheme illustrated in Figure 2 (box 2). However, the campus argues that its 100% green energy supply comes without an

emission cost [29], which is in line with sector logic. Not only, again, that the campus neglect its responsibility that a complex energy supply infrastructure had to be installed at and around the campus, but it converted these expenses into a credit: The green energy supply would be “avoiding 240 tons of CO₂ per year” which would (over-)compensate the 6 tons of CO₂ emissions caused by business vehicles [29]. In contrast to these results, a complete accounting of all use-phase emissions of the same Umwelt Campus Birkenfeld based on LCA data arrived at 2696 t CO₂e/year, and the inclusion of embodied impacts increased this figure by another 332 t CO₂e/year [20]. This example makes it clear that some of the CO₂ emission numbers communicated by universities today are beyond any comparability.

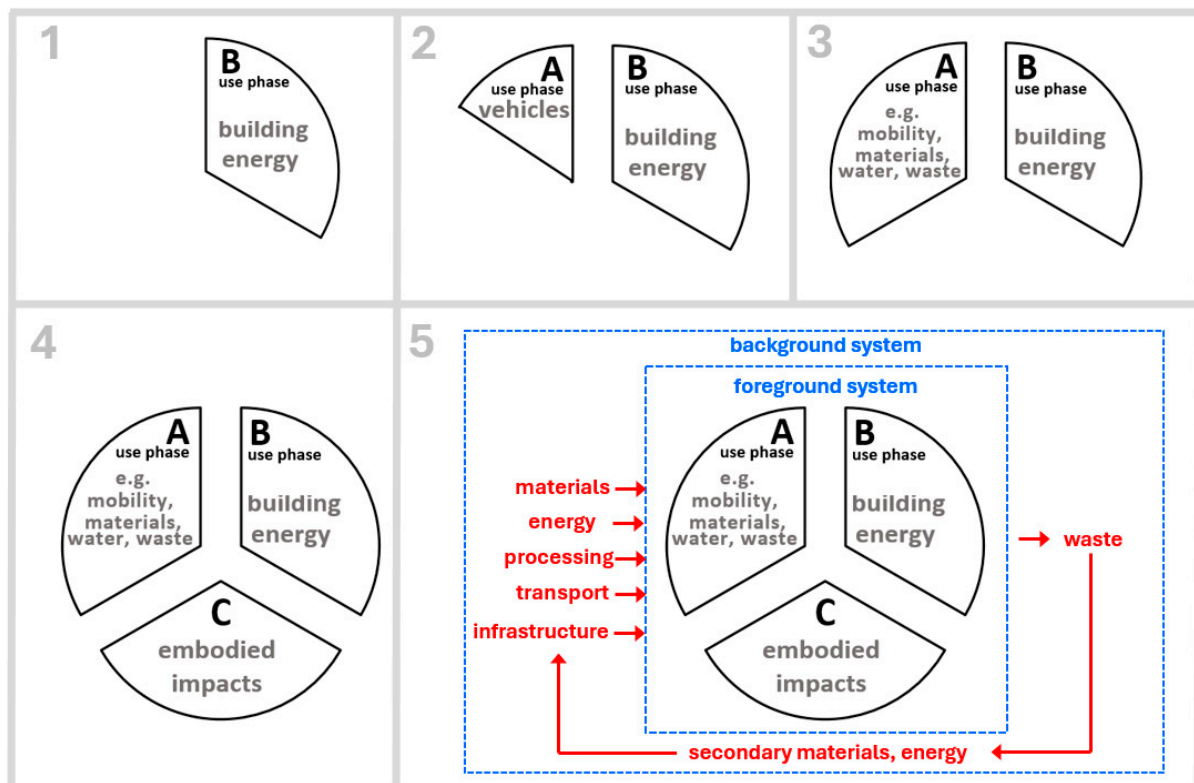


Figure 2. Different depths of analysis at university carbon footprinting currently applied (selection). (1) Reporting building energy only, (2) reporting building energy plus parts of further use-phase emissions like vehicle fuel consumption, (3) covering complete use-phase emissions, (4) adding embodied impacts to use-phase emissions, (5) considering upstream and downstream emissions.

Emissions Due to Infrastructure Measures and Long-Term Investments

Emissions from infrastructure and investment measures (e.g., building construction and equipment) constitute the third fundamental component of a university’s GHG balance (part C in Figure 1). Sanderson [45] asked the question, “who is responsible for (embodied CO₂)—the producer or the consumer?” He answered: “Today, the responsibility lays with the producer, which is not sustainable” [45]. The EU Commission has recently addressed this topic and is working on a roadmap aiming at reducing lifetime CO₂ emissions in building construction, which includes embodied impacts [46].

While there is some awareness among universities to consider embodied impacts in CO₂ accounting (e.g., [27,47]), just one article has been located reporting a university-wide embodied impact number of 1.4–10.0 kg CO₂/m² × year [48]. This is lower compared to the 13.7–26.3 kg CO₂/m² × year measured by [20]. This may be due to the fact that Dixit & Kumar [48] did not consider CO₂-equivalents, for example, as well as construction site expenses, which represented the highest proportion among the embodied impacts [20].

Maintenance and repair costs may also be recognized in the use phase, but they are part of the building life cycle (e.g., [49]), which is why they are allocated to part C in Figure 1.

The embodied impacts constitute an elementary component of carbon footprinting: The first campus-wide study [20] found a share of 11–20.8% of embodied (Part C, Figure 1) relative to the total emissions (A–C, Figure 1) at two university campuses in Germany and Singapore. Surprisingly, hardly any universities have covered and reported embodied emissions up to date. On the contrary, probably nobody would omit the battery production costs when assessing the GHG emissions of an electric car (see above). The question arises: why is there not comparably careful attention when it comes to the GHG balance sheet of universities?

King's College (London) is an exception as it covers investment measures: As a part of the carbon footprint included in its Climate Action Plan, the college reports a 72% share of supply chain emissions with a very high absolute value (107,000 t CO₂e) for the budget year 2018–2019 [50]. King's College totals all its procurement expenditures here, from consumables to the purchase of research equipment and building construction. However, this kind of single-value accounting to the specific year of investment is much too undifferentiated, thus preventing evaluating the climate efficiency of such investments and making it difficult to assess the university's climate performance in total (see below).

Because construction and other infrastructure measures occur intermittently over the years, these emissions must be prorated over the period of use.

On a campus level, this approach was applied for the first time at Umwelt Campus Birkenfeld (Figure 3) and Nanyang Technological University of Singapore [20]. In this analysis, the materials used throughout the campus were retrospectively determined by measurements on campus and with the help of architectural plans. Following that, they were converted to CO₂e emissions by applying LCA emission factors from the German Ökobaudat database [51]. The standardized European building use phase of 50 years was taken as a calculation basis here [20]. In the case of the Umwelt Campus Birkenfeld (Germany), emissions from the building infrastructure exceed those from energy consumption (Figure 3), which is due to the use of green (low carbon) energy paired with elaborated thermal insulation. In conclusion, infrastructure-related emissions can no longer be ignored.

Furthermore, climate-efficient investment decisions are only possible if based on an infrastructure-related emissions inventory. Two examples may illustrate this: The hot water piping system (district heating system) connecting the Umwelt Campus Birkenfeld (Germany) to a regional biomass power plant causes a significant emission expenditure, i.e., construction and maintenance of 0.75 kg CO₂e/m² × year. However, compared to the local standardized technical alternative, natural gas central heating for the campus, the district heating system amortizes after around 2 years only [20]. Second: At Umwelt Campus Birkenfeld, the walls and windows of existing buildings were retained from a previous use. This allowed the saving of 2.3 kg CO₂e/m² × year compared to the alternative construction of new buildings made mainly of concrete and reduced infrastructure CO₂e emissions (part C in Figure 1) by 14.4% [20].

Leuphana University Lüneburg (Germany) is one of the most GHG emission-efficient universities in the world. A very complex technology on campus generates a surplus of green energy, which enables the campus to compensate for further emissions in the use phase. Leuphana University Lüneburg, accordingly, constitutes a net zero-emission campus without buying certificates [52]. However, what about the construction costs of the complex technology required, and at which point does it amortize? The answer is unknown. Such gaps in the emission balances should be closed.

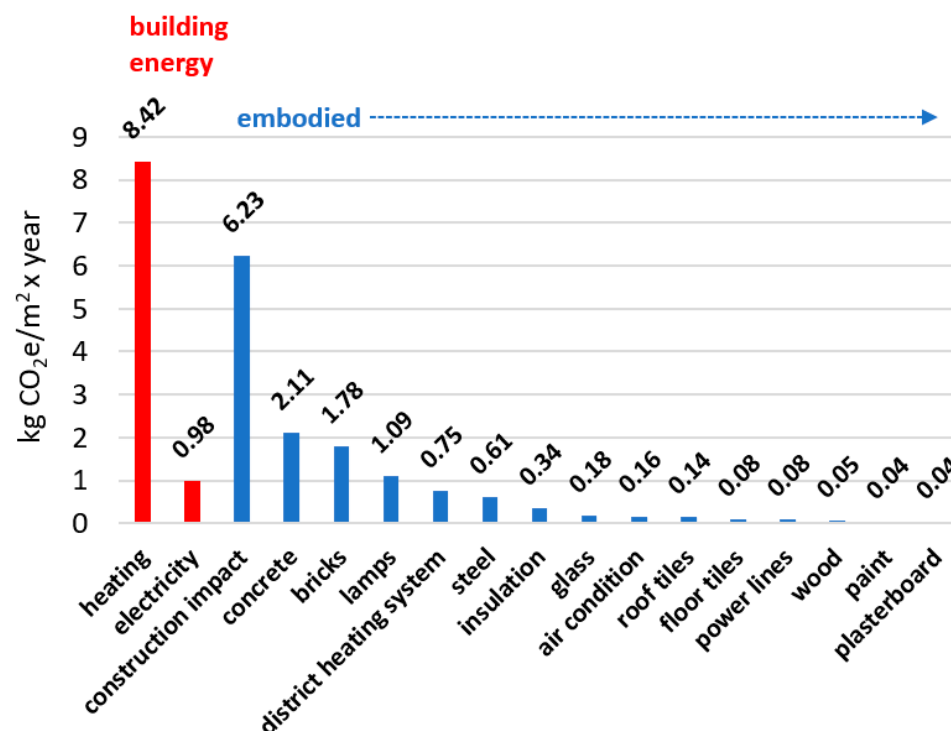


Figure 3. CO₂e emissions in the building life cycle at the Umwelt Campus Birkenfeld [20]. Comparison of building energy emissions (red, in total 9.4 kg CO₂e/m² × year, see B in Figure 1) and building construction, maintenance, and repair (blue, in total 13.7 kg CO₂e/m² × year, see C in Figure 1). All emissions are based on the number of square meters of constructed floor area and are related to the building's life cycle of 50 years. IMR (Inspection, maintenance, repair) is partly included in the respective materials [20].

3.2. Analysis of the Commonly Used Modeling Approaches During CO₂e Reporting

3.2.1. Territorial Carbon Accounting (Sector Logic) Versus Life-Cycle Assessment

There are two fundamentally opposing approaches when modeling GHG emissions on campuses: First, the kind of accounting according to the rules of the UNFCCC (United Nations Framework Convention on Climate Change), operationally implemented by the UN Climate Change Secretariat [2], and the IPCC (Intergovernmental Panel on Climate Change). This approach is also known as “territorial carbon accounting” [53] and is characterized by the so-called sector logic, or “sector thinking” ([54], see explanation below). More rarely, the term sector is replaced by the term category [55]. In contrast to this is the life-cycle assessment (LCA) approach (Figure 4). LCA can also be understood as an analog to the global reach of GHG footprints [53]. Both approaches are repeatedly intermingled in official state and institutional reports, as well as in the public and even the scientific debate, making the numbers presented sometimes almost impossible to disentangle. In gray literature reports, it is normally not specified on which modeling method the reported data are based. The figures determined by the two approaches can differ dramatically, as in the case of the Umwelt Campus Birkenfeld, Germany: from 6 t CO₂ applying sector logic [29] to 2696 t CO₂e [3] considering life-cycle impacts in the campus use phase. The sector approach is much easier and generates the more favorable (lower) numbers—it is, therefore, to be expected that this approach is preferred so far. In the following, the respective differences, intentions, and consequences of the two approaches will be discussed.

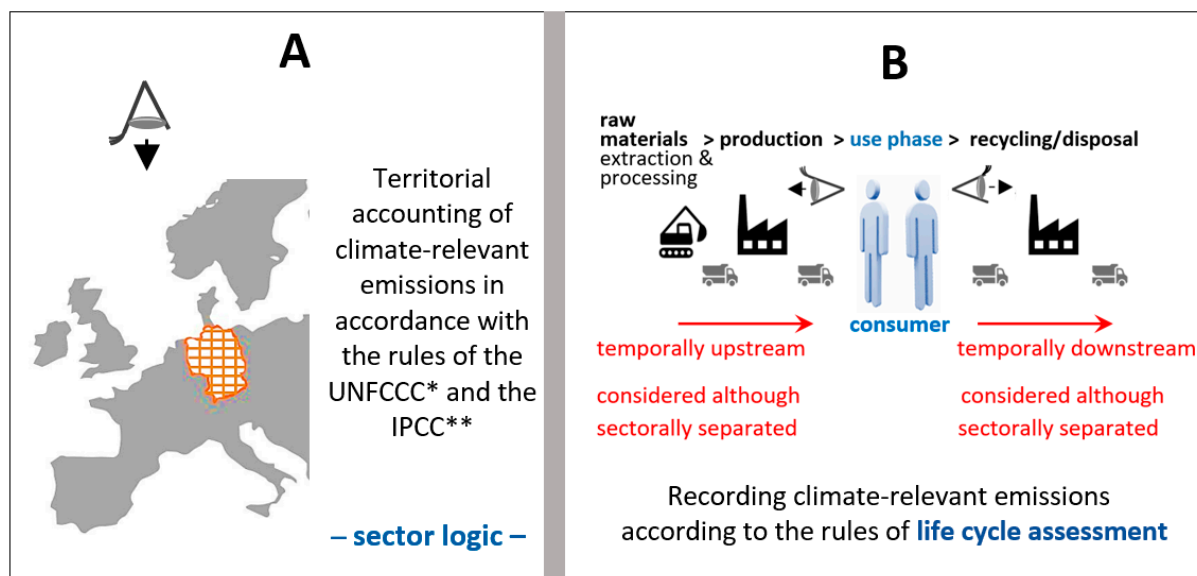


Figure 4. Competing schemes of emissions accounting ((A), sector logic; (B), life-cycle assessment) in current practice. (*) United Nations Framework Convention on Climate Change (UNFCCC), (**) Intergovernmental Panel on Climate Change (IPCC).

The Sector Logic

The parties to the Kyoto Protocol and subsequent international agreements on reducing GHG emissions have agreed to be monitored by UN organizations. To this end, a complex set of reporting rules has been created, which categorizes emissions in a variety of ways:

Within the national reports to the UN Climate Change Secretariat, emissions are divided into sectors (industry, agriculture, land use and forestry, energy production, waste, and wastewater) and various sub-sectors following the regulations [56]. Two main intentions are associated with this:

- (1) Global GHG emissions need to be specified as accurately as possible to enable current and future climate modeling. This is kind of a top rule: “Don’t count a gram of CO₂ twice”. The exact emissions of a country are not known, however. The more than 1000 pages of the German emissions inventory for 2022, for example, exhibit that the sectoral emissions are extrapolated by applying many models [56].
- (2) Solutions to decrease GHG emissions are sector-specific (“The sectoral solution to climate change”, [57]). For this reason, also IPCC [58] applies a detailed sector subdivision when evaluating reduction attempts (e.g., [58]).

In other words, UNFCCC and IPCC look at the world from above, so to speak, dividing countries from each other and subdividing them into sectors (Figure 4). Emissions are recorded over a defined period of time (usually 1 year). This is a kind of two-dimensional view (Figure 4).

The Consequences of Sector Thinking

However, dangers for climate protection arise if actors “on the ground” (i.e., private and institutional consumers) adopt the sector logic to balance their own emissions: The production-related emissions of goods imported from other countries, for example, remain unconsidered in the home country of the consumer, as these emissions are supposed to be recorded outside and ideally minimized or compensated for by local measures. Even within a country, one sector does not feel responsible for the emissions of another sector when it purchases goods and services there.

A prominent example of this approach is the electricity sector, which in Germany generally specifies an emission of 0.0 g CO₂/kWh in the case of renewable electricity, neglecting all infrastructure necessary to establish and run this technology. This, in turn, is very favorable for the mobility sector: Electric cars powered by green electricity are then considered zero-emission vehicles by modelers following sector logic. This “zero-emission mobility” (e.g., [31,32,56,59]), in reality, is based on a complex supply chain, which includes battery production, for example. Batteries, again, are made consuming a lot electricity [60]. As a result, LCA modeling showed that the battery alone could make up between 13% and 36% of the life-cycle CO₂e-impact of a mid-sized car, depending on whether the battery is made with electricity originating from windmills versus electricity mainly from coal-fired powerplants ([30], see additional explanations related to LCA below). This example illustrates that it is impossible to assess the climate friendliness of, e.g., an electric car without considering emissions along the supply chain, which, however, sector logic does.

China is, to stay with this example, the by far biggest producer of electric traction batteries [61]. Due to the dominating electricity production from coal-fired power plants, the electricity carbon footprint in China was relatively high, with 585 g CO₂e/kWh in the year 2022 [62]. This causes high upstream emissions during the production of batteries for electric vehicles.

Universities, to come back to them, operate business vehicles among other infrastructure. It is up to universities to decide which method they will use to model the emissions of their vehicles.

Surprisingly, although the former European Commission has declared a “Green Deal”, which particularly includes the ambition to move the continent towards less and finally zero CO₂e emissions [63], a huge part of the European battery cell industry is currently built up in Poland [64,65]. Poland has the second highest electricity carbon footprint in the EU with 681 g CO₂e/kWh in 2022 [66], an emission which is higher than that from electricity production in China (see above). Nevertheless, the Polish battery industry is subsidized by the EU Commission [67] next to industry from further European regions. However, battery production in Germany, which is also subsidized, still has a relatively high carbon footprint of electricity production, with around 400 g CO₂e/kWh in 2023 [68], much higher compared to Scandinavian countries, for example [66].

This, however, contradicts the target of decarbonizing the European continent because excess GHG emissions from one place would have to be compensated for by savings or CO₂ certificates obtained from elsewhere. Sector logic and country separation due to UNFCCC’s territorial carbon accounting are hiding these problems. In our world with very much diverging decarbonization rates, this approach is tantamount to greenwashing: There will not be any more or very little remaining CO₂e emissions only in one’s own country or sector, but at the price of possibly increased CO₂e emissions in an exporting country, because the industry in a foreign country needs to satisfy the increased consumer demand abroad.

This lack of or delegation of responsibility is widespread in sectoral thinking: For example, some gas and electricity grid operators take the view that the energy system they are operating is just a kind of energy transportation highway but has no CO₂ emissions itself [69]. This fails to recognize that transport efficiency determines the overall energy consumption and emissions of the entire system. Another problem is that institutions/companies that believe in their own emission neutrality usually cannot optimize and reduce emissions. For example, there is no regulation for electric vehicle (EV) energy consumption in the EU: all EVs are recorded with 0.0 g CO₂/km within the manufacturers’ CO₂ emission averages [70]. The resulting lack of innovation pressure led to a lack of energy efficiency improvements for electric cars [71,72].

In conclusion, sectoral thinking is the gold standard for the IPCC to properly count CO_{2e} and locate low-emission solutions. On the other hand, however, it can prevent institutional consumers from improving their emissions performance.

The Viewpoint of Life-Cycle Assessment (LCA)

LCA takes a very different point of view, which is the standpoint of the consumer as the responsible actor (Figure 4, right side). Climate impacts can never be zero here: There is always infrastructure needed for the manufacture and disposal of products or provision of services consumed. These upstream/downstream impacts are considered within a functional unit quantifying the impact during the use phase (e.g., for the car: a km driven). In other words, the life-cycle assessment increases resource-use efficiency and decreases liabilities [73]. In contrast, sector logic considers only direct use-phase emissions. However, even this would not justify the carbon footprint of green electricity to be zero: electricity-producing companies operate CO₂-emitting combustion vehicles, for example. Considering the whole life-cycle, photovoltaics, for example, produce electricity for around 80 g CO₂/kWh (this LCA impact was reported by IPCC [58]). Interestingly, the IPCC also abandons the sector logic in this context and does not specify “zero emissions” but “low carbon” or “net zero energy systems” [58].

Unfortunately, universities are not always so careful. Since its foundation, the Umwelt Campus Birkenfeld (Germany) has mistakenly marketed itself as a “zero-emission university” with a “CO₂-neutral energy supply” [74] or as “Europe’s first zero-emission university” because it is “completely supplied by renewable energy” [29]. Lishan College (Qingzhou, Shandong, China Shandong Normal University) was also reported to become a “zero carbon campus” by utilizing a 100% green energy supply [23]. In both cases, this involves consistent sector logic combined with a greatly simplified view of use-phase expenses (see below). The latter is reduced to energy consumption alone (B in Figure 1).

However, these individual cases are contrasted by thousands of universities around the world that have joined in “net zero” initiatives. Two examples: in 2021, 1050 universities from 68 countries pledged to achieve “net zero” by 2050 at the latest [75]. In the same year, 670 institutions from Canada joined forces with the same target [76]. The term “net zero”, which is also used by the IPCC since the 6th Assessment Report [77], means that zero emissions can only be achieved by offsetting remaining emissions (reviewed by [78]).

Correct LCA Emission Factors Available Only from Scientific Sources

Modeling a complete life-cycle assessment of an institution would be possible but usually far too time-consuming. Most of the services and goods consumed (Figure 1) can be converted directly into LCA-based CO_{2e} emission impacts if the correct emission factors are selected. Stridsland et al. [14] suggest requesting them from the suppliers of the goods and services ordered. This currently seems to be impossible in Germany, for example. The purchasing department of the university of the author is not aware that suppliers communicate such emission factors, apart from electricity companies. However, industry often determines LCA factors of products and services, and, sometimes, these numbers are communicated to customers for advertising purposes. During his professional life, however, the author has always warned his students not to believe LCA data published by companies. The reason for this is that only those LCA data are publicly communicated, which promise sales promotion—disadvantageous LCA impacts of products on offer are never disclosed.

Although the EU Commission is planning to make environmental footprinting mandatory in the future [79], it hardly seems possible to make such a system fully transparent. For example, LCA emission factors are very sensitive regarding the modeling framework, particularly when it comes to the system boundaries applied (e.g., [80]). Customers, private or institutional, will not be able to follow such fluctuations even if all the details are communicated. On contrary, for example, several electric scooter fleet operators published carbon footprints but never revealed the survival time of the vehicles, which is the most

important modeling factor (reviewed in [81]). Such non-transparent LCA emission factors are worthless, which is why the UNEP also confirmed [82] that basic LCA data must be communicated transparently.

Ultimately, however, reliable LCA emission factors can be easily obtained from publicly available scientific sources if published by independent authors or institutions. IPCC reports are also a suitable source for LCA emission factors (see above). Furthermore, there are publicly accessible databases, in particular ÖKOBAUDAT [51], with comprehensive LCA figures on building materials. It would, in any case, be desirable to standardize, compile, and publish the emission factors used within a country for GHG accounting.

3.2.2. Reporting in Accordance with the Greenhouse Gas Protocol (GHGP)

Emissions reporting, according to the GHGP, has become the standard worldwide and is also dominating HEI carbon footprint reporting [22]. In order to understand the implications of the GHGP for the climate accounting of universities, the background of this standard and its approach must be reviewed. The GHGP is based on an operationally defined reporting system that was initiated over 20 years ago to offer companies a simplified entry into GHG accounting [34]. The GHGP was also understood as an element of corporate social responsibility reporting (CSR) [83]. The origins of the GHGP go back to preliminary work by the World Resources Institute (WRI) with the cooperation of the oil and automotive industries, which was completed in 1998 [35]. Subsequently, the WRI and the World Business Council for Sustainable Development (WBCSD) cooperated to develop the GHGP for GHG accounting. This first standard was published in 2001; the joint website at this point again emphasizes the involvement of the electricity and oil industries in this project [35]. The WBCSD, in turn, is a global association of 225 large companies from various sectors, including primarily car manufacturers and companies in the steel, oil, and chemical industries [36]. The World Resources Institute is an NGO based in Washington. It is funded by governments and government-related institutions, but also by a number of WBCSD member companies [37]. In other words, the industry whose emissions mainly cause global warming developed and emphasized the application of the GHGP as a global GHG accounting standard. The GHGP, therefore, represents an industry-own GHG accounting system—developed in parallel or as a competitor to the Kyoto Protocol.

Historically, there are 3 scopes (fields) in GHGP accounting (Figure 5): Since 2001, Scope 1 and Scope 2 emissions have been recorded, originally related primarily to the combustion of fossil fuels. The categorization according to Scope 1 and Scope 2 creates initial confusion, as larger companies (as well as universities, of course) that have their own power plants classify such emissions in Scope 1, while smaller institutions purchase the energy and classify it accordingly in Scope 2. The emissions, according to Scopes 1 and 2, are therefore not necessarily comparable at different institutions.

Scope 2 introduces the term “indirect” emissions (Figure 5), which means these do not happen directly at the organization’s ground and assets. Scope 3, in turn, may be understood as an extension of Scope 2 but not related to energy alone. Scope 3 includes emissions that the organization indirectly affects in its value chain [84]. Figure 5 names all components of Scope 3 that are relevant to campuses due to Stridsland et al. [14].

The option to record Scope 3 emissions was already added in 2011 to the standard [35] but is currently (2024) still voluntary [85]. For the first time, in California, the mandatory inclusion of Scope 3 in reporting will first apply in 2027 for companies with an annual turnover of more than USD 1 billion only [86], 16 years after the addition of Scope 3 emissions to the GHGP. Unfortunately, universities are not at the forefront of the voluntary inclusion of Scope 3 emissions: Only 8 out of 135 studies published since 2003 have covered Scope 3 emissions [7].

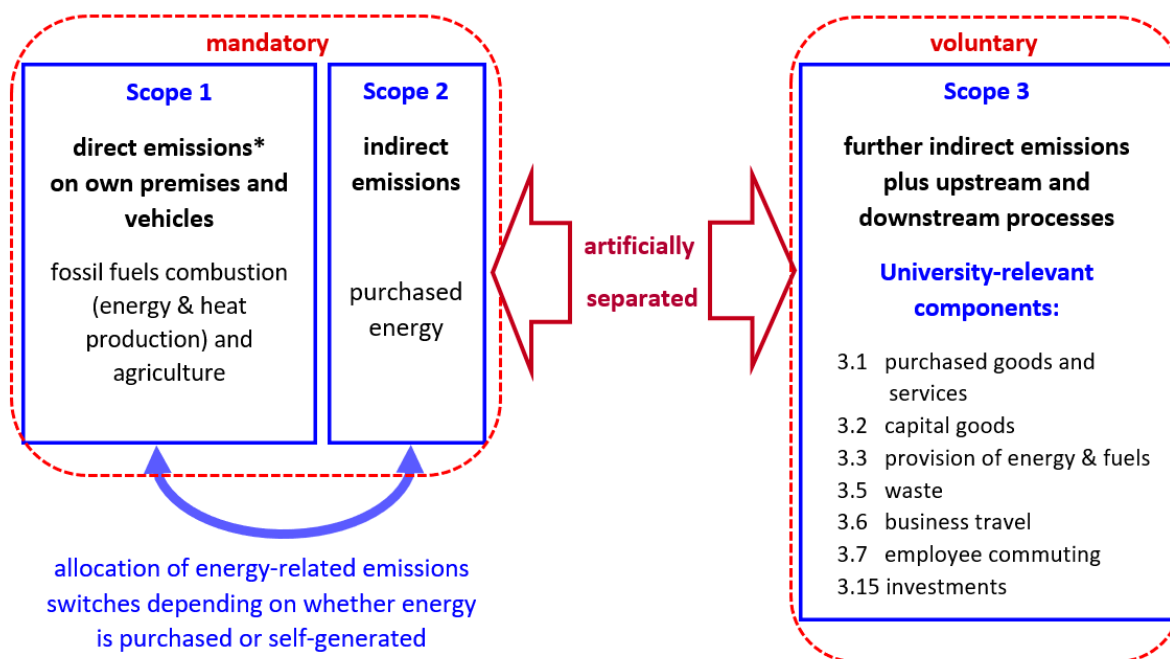


Figure 5. GHG reporting according to the greenhouse gas protocol (GHGP). University-relevant shares in Scope 3, according to Stridsland et al. [14]. (*) Direct emissions are emissions from facilities owned or controlled by the institution [34]. Note: CO₂, CH₄, N₂O, HFCs, PFCs, and SF₆ are each accounted for and converted to metric tons of CO₂e [34].

The separation of emissions into the Scopes 1, 2, and 3 emissions prevents a direct comparison of procurement alternatives. Mobility may again serve as an example: The fossil fuel consumption of company vehicles is converted directly into CO₂ emissions and assigned to Scope 1, while the provision (production) of the vehicles would be categorized in Scope 3.2. In the case the institution becomes aware of further fuel consumption alongside this activity, it can voluntarily add this consumption to Scope 3.3 (Figure 5).

This is different from the LCA methodology. LCA is quantifying the cost of a certain product along its life cycle. For example, around 25% of CO₂ emissions must be added to the direct combustion balance of vehicles [87] because of losses in the fuel provision chain. According to GHGP, on the contrary, Scope 3 fuel consumption is also directly converted into CO₂ emission based on its carbon content [88], neglecting CO₂ equivalents.

As this example illustrates, the distribution of GHG emissions of the same item across three Scope subgroups makes it difficult, if not impossible for an institution to identify the most emission-efficient alternative: is it electric or internal combustion engine vehicles? The answer to this question, on the other hand, has been the subject of many LCA studies of vehicles and reviews (e.g., [89]), so the correct emission factors are easy to locate.

To stay with this example, accounting institutional vehicle emissions according to the GHGP Scopes 1/2 underestimates mobility emissions from vehicles. This may be surprising, as it has been known since the establishment of LCA as an international standard in 1997 [28] that the entire life cycle of a product must be taken into account in order to correctly assess its environmental relevance (global warming is addressed as one of the most important impact categories in LCA). It is noteworthy that the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD) developed the GHGP for GHG accounting [35] between 1998 and 2001, shortly after the establishment of LCA as a standardized method [28].

In the context of the timing described above, the GHGP may appear as a counter-design to LCA with the aim of protecting companies from too much transparency, responsibility, and expenses. Retail and logistics companies, for example, would have to develop more detailed GHG balances and possibly offset high transportation related impacts following an LCA-oriented emission modeling. Many such companies are among the members of the WBCSD [36], including the logistics market leader Amazon. The NGO World Resources Institute (WRI), the second initiator of the GHGP, reported the largest single donation of over USD 100 million from the Bezos Earth Fund [37], founded by Jeff Bezos, who is also the founder of Amazon. The description of these connections appears important against the background of the question of how universities should deal with GHG accounting.

3.3. The Standardized GHG Emission Performance Metric

After compiling an emissions inventory that is as comprehensive as possible, the question arises of how the university performs in comparison to others. Many institutions, however, communicate their raw emissions in tons of CO₂e per year. However, this figure alone is meaningless for the public and the university, as this does not allow any assessment despite comparing emissions from earlier years. For standardized comparison purposes, there are two key figures established in the literature: CO₂e emissions per capita and per m² of building floor area. Sometimes, the emissions are based on a per-student basis only [24], but this is not recommendable because most HEIs are not just educating but also doing research. Helmers et al. [3] have suggested that CO₂e emissions should also be related to the financial expenditure of the university (excluding salaries) in order to generate a third carbon performance parameter.

However, HEI Carbon footprint performances, which are calculated based on non-validated numbers unlike those presented in Figure 6 (i.e., not amended by missing impacts, for example), or performance data related to one school of a university or one building only (e.g., [7]), or related to students or staff only [15] instead of the whole population can deviate greatly from the values depicted in Figure 6.

A validated overview of university GHG performances worldwide, on the other hand, allows the suggestion of classification into quality ranges, indicated with the colors green, yellow, and red (Figure 6):

- Green: Good climate performance: up to 100 kg CO₂e/m² × year, and up to 1 ton CO₂e/capita × year, respectively
- Yellow: Average climate performance: 100–200 kg CO₂e/m² × year, and 1–3 tons CO₂e/capita × year, respectively
- Red: Unfavorable climate performance: >200 kg CO₂e/m² × year, and >3 t CO₂e/capita × year, respectively

This kind of global overview also exhibits that both large and small HEIs, even those with a complex infrastructure, can achieve a favorable climate performance [3].

While Figure 6 comprises use-phase emissions only, Umwelt Campus Birkenfeld (Germany) and Nanyang Technological University (Singapore), for the first time, were modeled, including embodied impacts. This comparison surprisingly revealed very similar floor-related emissions of 124.5–126.3 kg CO₂e/m² × year [20], although the two universities differ greatly: The Umwelt Campus Birkenfeld is a small university with relatively simple infrastructure, located in the climatically temperate Germany, while Nanyang Technological University Singapore is based on a very large campus with complex infrastructure at a tropical location.

In a data comparison such as that shown in Figure 6, even if all relevant individual items according to Figures 1 and 2 are considered, and despite the inclusion of Scope 3 impacts, an imprecision of the not fully comparable emissions according to LCA and GHGP remains.

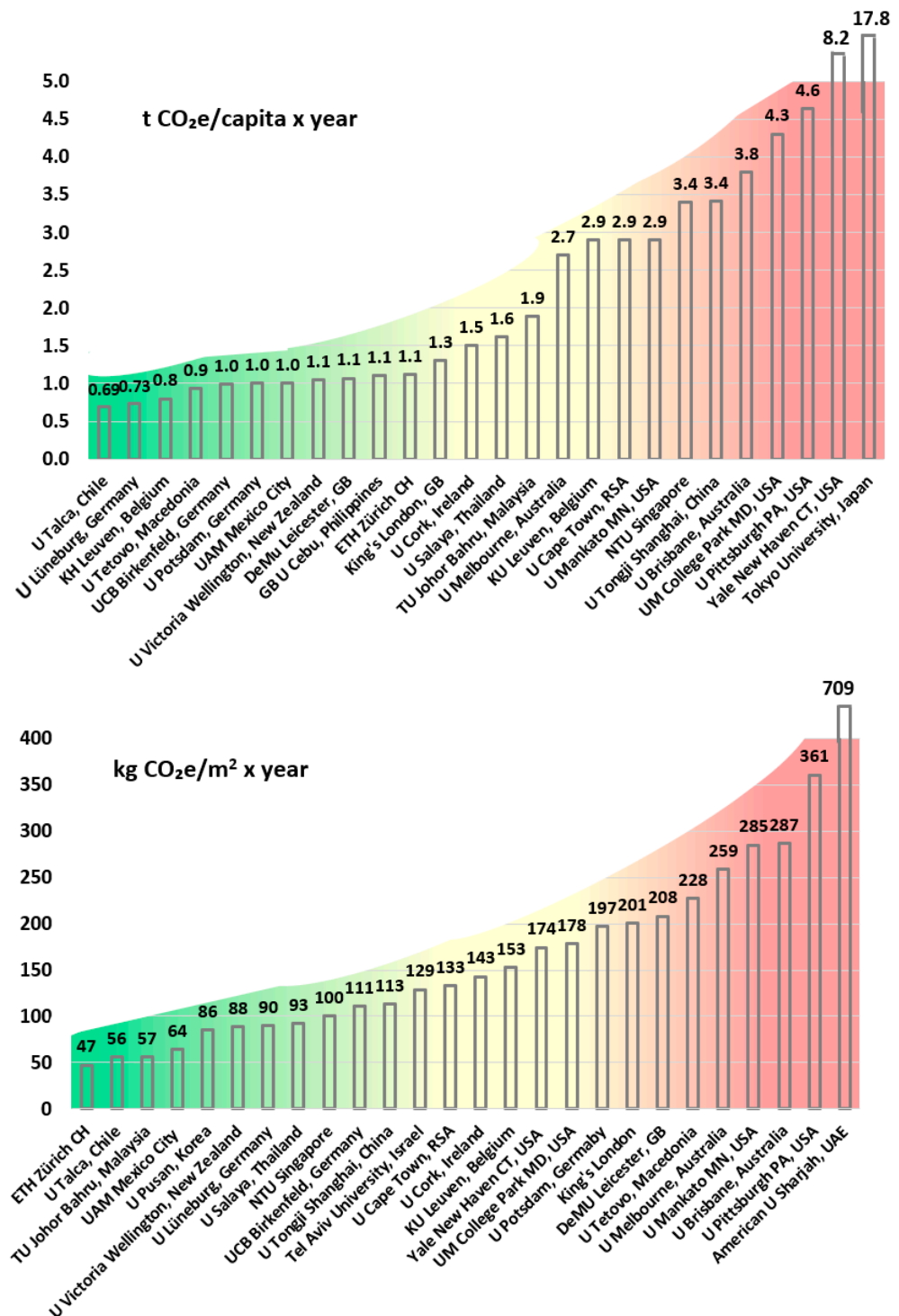


Figure 6. Population and floor area-related climate performances of 26 universities worldwide. Related to use phase (A + B, Figure 1) emissions only, and without offsetting measures. Note: Most of the figures published by the respective universities were validated, corrected, and partially supplemented by missing impacts and taken from Helmers et al. [3], here again re-corrected and extended. Data added for Tel Aviv University [38], American University at Sharjah [40,90], University of Tokyo [41,42], Pusan University [25], and Victoria University Wellington [39,43]. Only data including Scope 3 emissions and pre-Corona numbers (up to 2019) considered. t = metric tons.

4. Perspective Assessment and Evaluation

Various reasons for incorrect or incomplete documentation of GHG emissions on campuses were discussed in this article (Table 2). The largest degree of emissions underreporting is due to the application of sector logic (accounting problem No. 1, Table 2). The only partial consideration of use-phase emissions can also lead to considerable underestimates (accounting problem No. 2, Table 2).

Table 2. Summarizing accounting problems (1–5) in the current HEI carbon emission inventories.

No.	Carbon Accounting Problem	→	Impacts If Problems Not Solved	→	Conclusion, Recommended Action
1	Sector logic $\leftrightarrow$ LCA-oriented accounting		Results not comparable, zero emissions may be claimed following the sector logic, lack of emission reduction measures		Only LCA is fully addressing the institutional responsibility
2	Different coverage of emission sources at campuses		Results not comparable, particularly if mobility impacts are missing		Catalog of internationally recommended impacts [3] should be covered
3	Only direct emissions are taken into account, without provision and disposal costs, or both are artificially separated (separating emission sources by scopes 1–3 in the GHGP)		Results not comparable between campuses and/or not transparent		upstream and downstream emissions considered in LCA
4	Hardly any university recognizes infrastructure and investment costs today, or these costs are not converted to yearly costs		Emission efficiency of energy and construction measures cannot be assessed. Institutional responsibility is not comprehensively being addressed.		Recognize infrastructure and procurement expenses over a lifetime and convert them to annual values. Separate use-phase and long-term investments in reports
5	The units CO ₂ and CO ₂ e (equivalents) are mixed up, confused, or equivalents are omitted		errors up to 46.7%		Apply LCA factors; they always contain CO ₂ e equivalents

HEI = Higher education institute, LCA = Life-cycle assessment.

The categorization of emissions according to scopes based on the GHGP also generates partly incompatible figures (accounting problem No. 3, Table 2). Unfortunately, the only institution dedicated to collecting and publishing university CO₂e emissions, which has been established so far internationally, the Sustainability Tracking, Assessment and Rating System STARS [91], is comprising Scope 1 and 2 emissions only following the GHGP. This paper does not recommend following the GHGP in campus inventory building because this scheme is neither responsible nor comprehensive.

Emissions due to (new) infrastructure established at campuses are almost never covered in GHG reports so far (accounting problem No. 4, Table 2).

A very common cause of data uncertainty (No. 5 in Table 2) is the mixing of the units “CO₂” and “CO₂e” (equivalents). The two different units are cluttering even in the scientific literature and, subsequently, of course, also in the gray literature. It frequently happens that, without explanation, CO₂ instead of CO₂e emissions are reported [92], or CO₂e-based numbers are changed to CO₂ emissions without communicating the error [93], and sometimes the “e” is omitted or forgotten. The data error is potentially significant: methane, N₂O, and F-gases together cause 46.7% of global warming, based on the years 2010–2019 and relative to 1850–1900 [77].

4.1. Sector vs. LCA Thinking in GHG Emissions Reporting

The application of sector logic would, in the end, still be locally justifiable if (1) all countries would be decarbonizing in parallel, (2) there would be supply chain CO₂e emission quantification and compensation, or (3) in the case of local supply chains instead of globalized trade. We do not live in such a world; instead, the local decarbonization

targets diverge significantly (see above). The decisive factor here is the weight of China, the globally dominant economy with 35% of global gross production and 29% of global value-added [94]. China is Germany's largest trading partner [95], for example. At the same time, China is currently responsible for over half of the global CO₂ emissions from coal-fired power generation [96]. These are expected to fall by approximately half by 2050, while in parallel, increased coal-fired power generation emissions from India could compensate for the Chinese decline [96]. Assumptions about greater declines in coal-fired power generation in China, on the other hand, are apparently mere projections that illustrate the theoretically necessary path to a 1.5 or 2-degree global climate goal [62,97]. Following extrapolations from other sources, it appears that Chinese coal-fired power generation will continue to increase until 2035 and then stagnate until 2040 [98]. In conclusion, there will not be any reason to neglect supply chain emissions in the foreseeable future.

The European Union is currently planning new regulations to counteract carbon leakage due to relocating energy-intensive production to countries with higher CO₂ emissions: Imported goods are planned to be taxed according to a "Carbon Border Adjustment Mechanism" [79]. However, importers will not have to pay any financial levies until 2026 [99]. It seems hardly conceivable that CO₂ import duties would restrict the rules of globalized free trade in such a way that higher-CO₂ countries would have to fear export losses, even if such duties appear possible under WTO law [100]. In addition, the question arises as to how carbon offsetting measures can be successfully implemented by investing the collected taxes.

In conclusion, in the foreseeable future, state authorities will not remove the responsibility from HEIs to care for their own emission impacts. Universities must, therefore, accept their own emissions responsibility (Table 1) instead of shifting it to other actors, sectors, or countries. Consequently, this means adopting an LCA perspective to recognize the supply chain CO₂e costs of their own consumption. In this situation, sectoral thinking would be greenwashing the CO₂e emissions balance and, therefore, be a danger to the future climate. Only if responsibility is accepted and the emissions caused are fully recorded can they be reduced in the next step through suitable measures. Universities have already developed many ways to decrease their emissions (reviewed by Aghamolaei & Fallahpour [4]).

4.2. Applying the GHGP to Educational Institutions

To date, the application of the GHGP leads—based on Scope 1/2 reporting—to incomplete, non-transparent GHG balances, which, when Scope 3 is taken into account, continue to be confusingly structured and obscure the actual environmental costs. This contradicts the target of responsible, transparent, and comprehensive reporting, which was formulated at the beginning. The subdivision of reporting into Scopes and the separation of some provision and indirect expenses into the voluntary Scope 3 results in an analogy to the sector logic of territorial carbon accounting and causes again a delegation of responsibility for climate-relevant emissions, in this case to suppliers and export countries (Table 3).

While LCA tries to determine the total environmental costs, the GHGP has created a hurdle in that Scope 3 emissions can but must not be recorded separately. Because this seems to be difficult for companies, the software industry has developed a range of digital tools to calculate Scope 3 emissions [101]; the company IBM, for example, has integrated such tools into comprehensive "foundation models" with multiple statements on climate modeling aspects [102].

What can universities do to act correctly in this complex situation? They can jointly develop databases to determine conversion factors for the accounting of their expenses according to Scope 3 [14]. In the author's view, however, LCA results in a much more complete understanding of a campus' footprint (Table 3). On top of that, LCA functional units enable the selection of the most climate-efficient activities like mobility (here, the life-cycle impact is given in g CO₂e/personal kilometer traveled (PKT) (e.g., [103])).

Table 3. Brief comparison and conclusion of accounting methods applied in campus carbon footprinting.

Accounting Method	Territorial Carbon Accounting (Sector Logic)	Accounting Due to Greenhouse Gas Protocol (GHGP)	Accounting Based on Life-Cycle Assessment (LCA)
Principles, components	Strictly focussing on own on-site emissions	On-site emissions mandatory, “indirect” and supply chain impacts voluntarily covered only	On-site (use-phase) as well as upstream and downstream emissions are included in life-cycle impacts. LCA quantifies functional units
Main motivation	Separating actors and sectors from each other	Make it as simple as possible to count emissions [33]	enable a comprehensive evaluation
Consequences when applied on campuses	prevents comparability	Separation into scopes 1–3 artificial, results not comparable due to different coverage of scopes and components	Highest level of emissions completeness, enables the university to make reasoned procurement decisions
Level of responsibility	From none to low	Medium	High

For the reasons described above, the GHGP scopes are not suitable for public reporting by universities. The university should, by contrast, publicly communicate LCA-based GHG emissions based on a comprehensible categorization of its activities (Figures 1 and 2) and, if requested by state authorities, in addition, report according to the GHGP.

5. Conclusions

In conclusion, this analysis has revealed:

- The three main directions of GHG accounting applied at HEIs to date are incompatible with each other. Their results can differ by orders of magnitude.
- In particular, sector logic and LCA are almost diametrically opposed approaches, while GHGP accounting falls roughly between the two regarding the coverage of emissions.
- In particular, it is the sector logic in accounting that often prevents responsible climate action right from the start. It is neither responsible, nor transparent, nor complete. It can induce institutions to neglect that they have any relevant GHG emissions or responsibility for emissions along the provision chain.
- Reporting due to the GHGP is simple but not suitable as a standard because of its artificial, operationally defined structure: the emissions in Scope 3 are recorded voluntarily only but are nevertheless important. GHGP data of different universities may not be comparable. Emissions of central campus activities like mobility are split into several scopes.
- Only LCA considers provision costs automatically. The functional units LCA modeling generates allow the selection of the most efficient alternatives in the management and operation of a campus. It is not necessary or recommended to run a full LCA modeling of a campus but to determine the emission balance based on the inventory measured and scientific LCA emission factors.
- The abundant different analytical depth universities are applying when recording GHG emissions, in connection with changing combinations with LCA elements, creates further incomparability of existing data.

Universities need to decide whether to adopt a highly simplified view of their emissions responsibility (e.g., by “territorial carbon accounting”) or to strive for comprehensive modeling and thus accept their responsibility. Standardization of the procedure would be very welcome, but preferably not (only) based on the GHGP.

By comprehensively recording GHG emissions according to the standards of LCA, universities would be able to provide their graduates with these competencies. They would be leading the way for other institutions, sectors, and countries. If all institutions worldwide were to record and offset their GHG emissions according to LCA rules, this

would theoretically result in GHG overcompensation. However, such an overcompensation will not occur in the decades ahead in view of the very different decarbonization rates at a local level and the decarbonization targets that have been set very far into the future.

The IPCC [104] sees the global climate heading towards an average warming of 3.2 degrees in view of the global measures and plans currently promised to combat climate change. This would be very difficult to compensate for—so any greenwashing or simplification in emissions accounting should not be accepted.

6. Note

The use of the units CO₂ and CO₂e in the text has been adapted to the unit in the respective literature source cited; general statements refer to CO₂e emissions (here used as synonyms: greenhouse gas emissions, carbon accounting, carbon footprinting, climate-relevant costs). CO₂e refers to CO₂ emissions, including CO₂ equivalents (e stands for equivalents). The unit t refers to metric tons.

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Glossary

F-gases	Gases containing fluorine
GHG	Greenhouse Gas
GHGP	Greenhouse Gas Protocol
HEIs	Higher Education Institutions
IMR	Inspection, Maintenance, Repair
IPCC	Intergovernmental Panel on Climate Change
LCA	Life-Cycle Assessment
NGO	Non-Governmental Organization
UNFCCC	United Nations Framework Convention on Climate Change
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute
WTO	World Trade Organization

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