Employee mobility and service-related management in the carbon footprint of services—German case studies

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Abstract
Purpose In a service society, the assessment of climate-relevant environmental impacts of services is of increased importance. In the few Product Category Rules (PCRs) for cleaning services available to date, it is noticeable that employee mobility and service-related management are excluded from the assessment. This practice is critically questioned in the following study. The aim is to show that a calculation of the carbon footprint of services that integrates employee mobility and service-related management provides a better basis for finding ways to reduce their environmental impact.

Methods Key figures on the CO₂e emissions of services are examined in exemplary case studies using the example of cleaning, maintenance and reception with regard to the possible share of emissions caused by employee mobility and service-related management activities. For the case studies located in Germany, characteristic values of the equipment, operating materials or mobility used for the service are obtained from available Environmental Product Declarations (EPDs). In the absence of EPDs, a simplified estimate is made according to the VERUM method based on the proportion of materials in the product. The case studies compare the carbon footprint of a service by omitting and including employee mobility and service-related management.

Results The analysed case studies show an impact share between 32 and 69% for employee mobility and between 10 and 26% for service-related management activities in an integrated carbon footprint of services. The emissions caused by employee mobility and service-related management therefore have a dimension that should not be neglected.

Conclusions From these findings, the necessity is derived to include the emissions from the mobility of operational staff and service-related management in future PCRs for services in order to improve the comparability of services. Optimisation efforts of companies must also start at these points of the service organisation.

Keywords CO₂e emissions · Service · Mobility · Carbon footprint · Product Category Rules · Commuting · Overheads · GHG Protocol

1 Introduction

As awareness of the carbon footprint of current economic activity (Lawn 2016) increases, the accounting of greenhouse gas emissions for services is also coming into focus (Wood 2017). In a knowledge society, services account for a high share of value creation, e.g. 70% in Austria (Statistik Austria 2021). Services are ‘an intangible product and cannot physically be touched’ (Mosadeghrad 2013). They are often characterised by high indirect CO₂e emissions along the value chain (Hertwich and Wood 2018; Klaaßen and Stoll 2020; Suh 2006; World Resources Institute and World Business Council for Sustainable Development 2011a). An example of this is the healthcare industry, whose indirect CO₂e emissions along the value chain can account for 71% of total emissions (Karliner et al. 2019; Nansai et al. 2020). From the perspective of companies and institutions, employee mobility attributed to scope 3 under the Greenhouse Gas (GHG) Protocol (World Resources Institute and World Business Council for Sustainable Development 2011b) is currently becoming more of an issue (Robinson et al. 2018).

Life cycle assessment is covered in ISO 14040 AMD 1:2020 ‘Environmental management—Life cycle
assessment—Principles and framework’ (ISO 2020), ISO 14044 AMD 1: 2019 ‘Environmental management—Life cycle assessment—Requirements and guidelines’ (ISO 2019), ISO 14067:2018 ‘Greenhouse gases—Carbon footprint of products—Requirements and guidelines for quantification’ (ISO 2018) and other environmental management standards (Finkbeiner 2014). These interlinked standards define the process of a LCA as divided into four steps: goal and scope definition—including the definition of the functional unit (FU), life cycle inventory analysis—including all input and output flows (Weidema et al. 2018), impact assessment and interpretation. The impact assessment uses, amongst other categories, the impact category ‘Global Warming Potential’ (GWP), which is expressed in CO₂ equivalents (CO₂e).

However, this general methodology leaves great freedom in the choice of system boundaries and the functional unit (Frischknecht 2020; Ruhland et al. 2000) for the calculation of the Carbon Footprint of Products (CFP). In order to make individual products comparable with regard to their Environmental Product Declaration (EPD), these freedoms of choice are reduced and specified on a product-specific basis in so-called Product Category Rules (PCR) according to ISO 14025 ‘Environmental labels and declarations—Type III environmental declarations—Principles and procedures’ (Del Borghi 2013; ISO 2006). Such PCRs exist for only a few services. On the environdec platform for PCRs and EPDs, only 14 PCRs are listed under the heading ‘service’, of which five are for construction services and three for cleaning services (The International EPD System 2021b). The ‘PCR 2011:03 Professional cleaning services of buildings’ (The International EPD System 2021a) states that employee mobility and service-related management should not be taken into account. Similarly, ‘PCR 2017:02 Professional cleaning services for passenger trains, UN CPC 853’ states that the following activities are excluded: ‘business travel of personnel, travel to and from work by personnel’ (The International EPD System 2021b).

Another system used in parallel to ISO 14067 to determine the carbon footprint (Kronborg Jensen 2012) is PAS 2050:2011: ‘Specification for the assessment of the life cycle greenhouse gas emissions of goods and services’. It is compliant with the principles of ISO 14040 (PAS 2050 2011). Its statements include very detailed information on the influencing factors to be included. For example, 5.1 requires that emissions associated with the ‘operation of premises’, including offices, are considered for the CFP (Garcia and Freire 2014; Gibassier and Schaltegger 2015). Amongst the aspects that are explicitly not to be taken into account is ‘transport of employees to and from their normal place of work’.

The Greenhouse Gas Protocol refers to the basics of ISO 14040 as well as PAS 2050. It distinguishes between direct and indirect emissions of greenhouse gases (Franchetti and Apul 2012). Scope 1 emissions are defined as direct emissions on the premises or from the vehicles and equipment of the organisation under consideration. Scope 2 includes emissions for the provision of electrical or thermal energy by external energy companies. Scope 3 includes indirect emissions from the corporate value chain (World Resources Institute and World Business Council for Sustainable Development 2011b), which arise from upstream or downstream processes that frame the actual production of goods or services. These emissions can arise, for example, from employee travels or commuting, purchased products or services in the supply chain, during distribution and use phase, and possibly in the end of life (World Resources Institute and World Business Council for Sustainable Development 2011a). Scope 3 emissions are typically collected at the company level. However, their public attention is increasing. For example, in its 5th Assessment Report, the IPCC also referred to indirect emissions under Scope 3 (Edenhofer 2014; Hertwich and Wood 2018).

In 2020, the German Facility Management Association (GEFMA) published the guideline GEFMA 162 ‘Carbon Management for Facility Services’ (German Facility Management Association e.V. 2021). This provides guidance on estimating CO₂e emissions in facility services, which can include numerous, very different services supporting the core business of facility management clients, from cleaning to maintenance and catering. The methodology in GEFMA 162 is based on the principles of ISO 14040 and the following standards. It provides guidance on allocating emissions through services from four areas: equipment, operating materials, transports and service-related management. GEFMA 162 thus makes statements that could possibly be found in a PCR for facility services. Emission figures per service and year are aimed for, if appropriate, related to the m² of the service area. The key figures determined in this way for each service can be analysed for carbon management with regard to drivers. Low-CO₂e alternatives must then be found and examined for these drivers. The tool carbonFM (Krämer et al. 2021) implements this method and offers its users some key figures. CarbonFM is therefore not a tool for creating a complete life cycle assessment, but supports the allocation of emission data for mapping the CO₂e emissions associated with a facility service. For this purpose, carbonFM uses existing EPDs for the products used in the service, if available, and enables a simplified estimation of emission data according to the VERUM methodology. VERUM 2.0 is the simplified environmental assessment of the Federal Environment Agency (Berger and Finkbeiner 2017). Its aim is to arrive at an initial plausible environmental assessment even without complete, quantitative investigations such as those carried out in a life cycle assessment.
The estimation can be made on the basis of the material proportions in a product.

A reference to facility management can be found in Dixit et al. who examine the contribution of facility management to reducing the carbon footprint of buildings, in particular through energy management (Dixit et al. 2016), and in Burritt et al. who highlight the involvement of facility management in data management for carbon management accounting (Burritt et al. 2011).

However, the question raised here as to how the service CFP should be calculated in concrete terms and whether employee mobility and service-related management should also be taken into account is not yet answered in the literature. The aim of the analysis is to present the potential shares of CO₂e emissions from employee mobility and service-related management for various services and to derive approaches for their integration into the PCR to determine the carbon footprint of services.

2 Methodology

The relevance of emissions from employee mobility and service-related management is demonstrated below on the basis of case studies. The case studies were defined in the research project CarMa—Carbon Management for Facility Services at the Berlin School of Economics and Law and the University of Applied Sciences in Berlin together with company partners from the practice of facility management (Pelzeter et al. 2020). The case studies are designed according to the system boundary and structure specified by GEFMA 162. The data for the case studies were collected from the companies involved. Information on equipment, operating materials and service-related management was provided. The data on employee mobility were estimated for the greater Berlin area.

2.1 Estimation of CO₂e emissions according to GEFMA 162

For the differentiated areas of equipment, operating materials, transports and service-related management, some details are provided below. An example for equipment would be the vacuum cleaner. Its emissions for production, transport to the place of use and end of life, which are ideally reported in an EPD, are divided by the service life and added to the service CFP as an annual contribution. If the equipment is also used in other, separately considered services, a percentage is calculated for allocation to the service CFP according to the share of use. The operating materials required for the use of the equipment, e.g. electricity or cleaning agents, are added to the service CFP according to the annual consumption.

The area of transports covers emissions of the respective service arisen from a regular movement of equipment and employees to different locations. Ideally, this also includes the employees’ journey from home to the place of work. The fourth area of service CFP is called service-related management. Service-related management activities include, for example, the activities of an object manager who coordinates the various facility services on site. Likewise, the service-specific coordinator, sometimes referred to as ‘customer manager’, is defined as service-related. In contrast, the general administration, including the personnel department and controlling, is not integrated. The service-related management emissions are calculated on the basis of office and equipment use as well as mobility and added proportionately to the service-related emissions — according to the share of hours spent on the considered service in the service manager’s total hours per year.

In the case studies, typical office properties were chosen as the subject of the services (Krimmling and Flanderka 2017). The data on time spent and the use of equipment and operating materials come from the company partners. For employee mobility, a total of 25 to 30 km per working day was assumed as the commuting distance in the greater Berlin area and a means of transport was defined.

However, no life cycle assessment was carried out for each service. Instead, a search was made for existing CFPs for equipment, operating material and transports, focusing on employee mobility. Where these were missing, which was the rule rather than the exception, an estimate was made using the VERUM suggestion: If no data for manufacturing processes is available in investigations, products can be evaluated in a simplified manner using material balances. ‘… In this way, material emissions and resource consumption can usually be accounted for with sufficient precision, as more than 80 percent of the impact are usually caused by material production.’ (translated form German original; Berger and Finkbeiner 2017). Thus, the end-of-life process is excluded. In the case of incomplete information on product components, the material with the highest carbon footprint per unit weight is used in the case studies. The publicly accessible databases Ökobaudat (Bundesministerium für Wohnen, Stadtentwicklung und Bauwesen 2022) and ProBas (Umweltbundesamt 2021a) are used for the carbon footprint of a product’s materials.

Due to the uncertainty of the estimated data and the lack of information on the processing of the material, a fixed surcharge of 50% is assumed and applied to the key figures for the provision of raw materials in the case studies described.

For electrical appliances used, the maximum possible power consumption of the appliance is assumed.
2.2 Basics for the calculation and optimisation of emissions from transports

The European standard EN 16,258:2012 ‘Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)’ (European Standards 2012) requires the reporting of four key figures: energy consumption and CO₂e emissions, each for ‘tank-to-wheel’ (direct emissions from vehicle operation) and for ‘well-to-wheel’ (including emissions and losses from fuel production).

The CO₂e calculators for transport emissions available online also represent the state of the art on this topic. However, a comparison of CO₂e calculators shows large differences in their results—a factor of 10–60 for personnel mobility (Bekaroo et al. 2021). Very concrete calculation specifications can be found in the Ecological Transport Information (EcoTransIT World Initiative 2019). These are the basis for the tremod Transport Calculator (Allekotte et al. 2020), which is used by the Federal Environment Agency in Germany (Umweltbundesamt 2021c) and operated by ifeu—Institute for Energy and Environmental Research, Heidelberg (ifeu 2021). The key figures on mobility used in the case studies are based on data from ifeu (Tables 4 and 5 in the Appendix).

This project focuses on emissions from employee mobility. Regular transport of equipment, e.g. lawn mowers, does not play a role in the services selected below. For the optimisation of employee mobility emissions, these are the basic strategies for improving sustainability: efficiency, consistency and sufficiency (Vielhaber et al. 2017). In relation to mobility, these are formulated as avoidance, shifting and improvement (Umweltbundesamt 2019).

• Sufficiency: For avoidance, a different service concept with combined service times or the introduction of remote maintenance for technical equipment can be considered.
• Consistency: Shifting is done by promoting the use of environmentally friendly means of transport, e.g. train instead of car.
• Efficiency: The improvement starts with the vehicle fleet, e.g. by purchasing fuel-efficient vehicles.

Examples of corporate mobility management are the formation of car pools, the provision of e-bikes and the promotion of the use of local public transport (Mittelstandsinitiative Energiewende und Klimaschutz 2018).

2.3 Basics for calculating and optimising emissions for service-related management (SRM)

According to the GHG Protocol, the ‘journeys’ of management are to be accounted for in the corporate value chain (World Resources Institute and World Business Council for Sustainable Development 2011a). PAS 2050 specifies that the ‘operation of premises’, including offices, is to be accounted for, which is also reflected in the rules of the GHG Protocol ‘corporate value chain accounting and reporting standard’ (World Resources Institute and World Business Council for Sustainable Development 2011a). It states that emissions over which the company has operational control should be included in the accounting, including emissions from mobility in company vehicles and from the company facilities building operation (especially from heating and electricity), proportionally depending on the used space and equipment (examples in Tables 6, 7, and 8 in the Appendix).

Concepts for reducing emissions through SRM refer to the abovementioned aspects that are directly related to a SRM workplace: office space management, equipment use and mobility. Sustainability strategies can also be mapped here:

• Sufficiency: replace mobility with video conferencing, reduce office space, e.g. through desk sharing.
• Consistency: use renewable energy sources for heating (Dadzie et al. 2019), purchase recyclable or repairable office equipment.
• Efficiency: Increase thermal insulation or rent office buildings with high energy efficiency (Gluszak et al. 2019).

2.4 Case studies for different services

The selection of services in the CarMa project was based on the requirement that different types of service provision should be shown and that these services should be provided relatively frequently in the area of facility management. Thus, the services cleaning, maintenance (of technical equipment) and reception were selected.

The analysis of the CO₂e emissions associated with employee mobility and service-related management (SRM) is carried out according to the specifications of GEFMA 162 and with the abovementioned key figures for employee mobility and SRM. The regular transport of operating resources is not relevant in the selected services and is therefore not further elaborated.

Formula 1: Carbon footprint of employee mobility (analogous to GEFMA 162)

\[
\text{CFP}_{\text{mob}} = \sum_{i=1}^{n} x_i \cdot D_i \cdot 2 \cdot T_i \cdot F_i
\]

CFP_{mob}: Carbon footprint of the mobility of all service employees per year, in kg CO₂e/a
x: Number of employees with the specification n
\[ D: \text{Distance, one way, in km} \]
\[ T: \text{Means of transport CFP, in kg CO}_2\text{e/person \cdot km, differentiate further if necessary} \]
\[ F: \text{Frequency per year} \]

Formula 2: Carbon footprint of SRM (analogous to GEFMA 162)

\[
\text{CFP}_{\text{SRM}} = \sum_{i=1}^{n} x_i \cdot I_i \cdot (S_i \cdot (Q_i + E_i) + F_i + J_i \cdot T_i) 
\]

\text{CFP}_{\text{SRM}}: \text{Carbon footprint of the SRM per year, in kg CO}_2\text{e/a}
\[ x: \text{Number of SRM employees with the specification} n \]
\[ I: \text{Percentage of hours worked by SRM employees for this service out of the total hours worked per year, in \%}. \]
\[ S: \text{Office space used by the SRM employees for this service in m}^2 \]
\[ Q: \text{Emissions due to the thermal quality and heating type of the office building, in kg CO}_2\text{e/m}^3\text{a} \]
\[ E: \text{Emissions due to quality of the electrical equipment of the office building (e.g. lighting, cooling), in kg CO}_2\text{e/m}^2\text{a} \]
\[ F: \text{Emissions due to equipment of SRM employees with digital terminals, in kg CO}_2\text{e/a} \]
\[ J: \text{Journey (total) per year, in km/a, differentiate further if necessary} \]
\[ T: \text{Means of transport CFP, in kg CO}_2\text{e/km} \]

The results are then compared with the service CFP, which was determined analogously to the PCR for cleaning ICE trains and hospitals. From this, the share of service-related emissions not taken into account according to the PCR is calculated.

The calculations according to the system of GEFMA 162—in the sense of an integrated service CFP—determine the emissions for the service provision during an entire year. The following services are modelled for an office building with 15,000 m\(^2\) of office space. Data sources: information by companies (Comp.), assumptions (Ass.), estimation according to VERUM (VER.), average value according to Krimmling and Flanderka (Aver.) and other as named below.

### 2.4.1 Cleaning

Dry cleaning with ancillary activity of emptying bins and dusting, partial wet cleaning.

- Area: 15,000 m\(^2\) office space (floor covering 80\% carpet; Comp.)
- Regular cycle: 1 \(\times\) per week (Comp.)
- Operating concept: 7 employees in parallel for 4 h on 2 days per week (evening cleaning; Comp.)
- Equipment: work clothes (EcoForum 2015), cleaning trolley (Falpi EPD, (Environdec 2022a), dry vacuum cleaner (VER.), mop covers (VER.), all quantities: Comp. (calculation example in Table 15)
- Operating materials: gloves (Carbon-connect AG 2018), garbage bags (VER.), vacuum cleaner bags (VER.), sponge cloths (VER.), floor and surface cleaning agent (ECOSÍ EPD; Environdec 2022b), power consumption of equipment (Umweltbundesamt 2021b) wastewater (0.03 kg/m\(^3\) according to information (email) from Berliner Wasserbetriebe), all quantities: Comp.
- Employee mobility: 7 service staff, travel 2 \(\times\) per week with public transport (Ass., Table 4), distance approx. 25 km (Ass.)
- Service-related management
  - 1 Customer manager (3\% of the annual activity, Comp.), office with 20 m\(^2\) (Comp.), high demand for electrical and thermal energy (Aver.), 40,000 km travel by car per year (Comp.)
  - 1 Object manager (5\% of the annual activity, Comp.), office with 20 m\(^2\) (Comp.), high demand for electrical and thermal energy (Aver.), 7500 km travel by car per year (Comp.).

### 2.4.2 Maintenance

Functional check, e.g. of a heating system, cleaning to maintain function, replacement of wearing parts, lubrication and adjustment.

- Number and type of systems: a flat rate of 20 units, heating, ventilation, cooling, sanitary systems, electrical equipment (Comp.)
- Frequency: 1 \(\times\) per year (Comp.)
- Operating concept: 10 \(\times\) per year for 1 day each on site for maintenance (Comp.)
- Equipment: work clothes (EcoForum 2015), toolbox with cordless screwdriver and measuring instruments (assumed with 75\% of mobile Phone iPhone X (Apple 2017), cordless vacuum cleaner (VER.), all quantities: Comp.
- Operating materials: gloves (Carbon-connect AG 2018), surface cleaning agent (ECOSÍ EPD, Environdec 2022b), power consumption of equipment (Umweltbundesamt 2021b), all quantities: Comp.
- Employee mobility: travel by service van (workshop van (Comp., 354 g CO\(_2\)e/passenger kilometre, own calculation), distance 30 km (Ass.).
- Service-related management:
  - 1 Head of technical services (0.5\% of the annual activity, Comp.), office with 20 m\(^2\) (Comp.), high demand for electrical and thermal energy (Aver.), 40,000 km travel by car per year (Comp.).
2.4.3 Reception service

Visitor assistance, acceptance of consignments, mail service, telephone service,

- Serviced area: 15,000 m² of office space. No individually used office space is assumed for the reception, as the workplace is usually integrated in the entrance area (Comp.).
- Presence: from 8 a.m. to 6 p.m., Monday to Friday, 255 days a year (Comp.)
- Operating concept: 10 h per day, 2 persons each 8 h and 6 h respectively (Comp.)
- Equipment: work clothes (EcoForum 2015), mobile phone (Apple 2017, telephone system is part of the facility), all quantities: Comp.
- Operating materials: (electricity for mobile phone is already included in the characteristic value for the mobile phone)
- Employee mobility: 2 persons travelling by public transport (Ass.), distance 25 km (Ass.)
- Service-related management:
  - 1 Head of infrastructural services (5% of the annual activity, Comp.), office with 20 m² (Comp.), high demand for electrical and thermal energy (Aver.), 40,000 km travel by car per year (Comp.).

The washing of work clothes and mop covers is assumed to be 1× per week at 60 °C (Verbraucherzentrale Rheinlandpfalz, Öko-Institut e.V. 2012).

2.5 Scenario for the optimisation of a service for CO₂e reduction

The demand made here for the inclusion of emissions from employee mobility and service-related management in the calculation of the CFP of services is based not only on the argument of the quantitative relevance of the emissions that would otherwise not be taken into account, but also on the argument that these emissions can be influenced better in the context of the service than in the context of the entire company. To prove the possible connection, the above case study on cleaning service is used for a scenario that includes the changes explained in Table 1. In the case of the modified equipment, the alternative vacuum dry cleaner has a lower power consumption than the one specified by the practitioners in the case study—and also less than required by EU legislation (no more than 900 W according to EU 666/2013 (European Union 2013)). This measure is categorised as an efficiency measure. However, efficiency can mean much more, e.g. reduced stand-by consumption or extended lifetime (Bobba et al. 2016). Activity, area and regular cycle of the cleaning service remain unchanged.

Table 1 Changes in the cleaning service to reduce CO₂e emissions

| Cleaning:     | Optimisation of equipment | Optimisation of operating materials | Optimisation of employee mobility | Optimisation of service-related management |
|---------------|---------------------------|-------------------------------------|-----------------------------------|-------------------------------------------|
| Operational concept: | Efficiency: dry vacuum cleaner with 400 W (e.g. Rowenta Silence force 4a +, (Mediamarkt 2022) instead of 2000 W power consumption (Öko-Institut e.V. 2021) | Efficiency: reduction of electricity consumption | Efficiency/sufficiency: 2 persons for day cleaning, 4×7 h |
| Equipment: | | | |
| Operating materials: | Sufficiency: waste bags only for wet waste (minus 97%) Washing of work clothes and mop covers at 30 °C instead of 60 °C | | |
| Employee mobility: | Efficiency/consistency Selection of employees with proximity to place of work (distance 20 km) | | |
| SRM: customer manager | Sufficiency: office: 15m² Efficiency: low demand for electrical and thermal energy Consistency: use of renewable energy sources | | |
| SRM: object manager | Analogous to customer manager | | |
| | | | |

**Optimisation of employee mobility** In this scenario, it is assumed that it is possible to switch from evening to daytime cleaning with fewer different staff arriving each time. This significantly reduces employee mobility. At the same time, however, this requires an intensive discussion with the service customer, whose own processes might have to react to this.

The distance of the journey cannot be reduced easily. However, a certain potential is seen in the targeted selection of employees depending on their proximity to the place of work. The means of public transport is already an optimum at assumed distances of about 20 km each way. A further potential for optimisation would only be to support the use of e-bikes.

Analogous to the worked out and calculated scenario of the optimised cleaning service, it is possible to work with the combination of journeys in maintenance, e.g. through the installation of remote maintenance options, and to differentiate the remaining journeys according to the extent of the tools used. If the tool demand is low, an e-bike can be used for the journey, for example. The possibilities for optimising employee mobility of the reception service are similar to those of the cleaning service.

**Optimisation of service-related management** The reduction of mobility emissions in service-related management through video telephony must also be coordinated in cooperation with customers and service employees. A reduction in emissions from office use can be achieved by renting or converting to energy- and space-efficient offices. There is a clear interface with the Corporate Carbon Footprint (CCF) here.

The concepts for reducing CFP through service-related management are similar for the different services.

**3 Results**

For each service, the CFP was determined according to the previous practice of the PCR for cleaning as well as according to the systematics of GEFMA 162 incl. staff mobility and SRM—referred to here as integrated CFP—for 1 year (see Tables 9, 10, 11, 12, 13, and 14 in the Appendix).

The total percentages of CFP disregarded according to the previous practice of PCR for cleaning include between 42 and 95% of the integrated CFP according to these examples (Table 2). The relative share of employee mobility regarding the integrated CFP varies in the above case studies between 32 and 69%, the share for service-related management from 10 to 26%. In any case, they take up a relevant share of the CFP.

Figure 1 shows that CFPs for services almost double when employee mobility and SRM are integrated. In the case of the reception service, there is even a multiplication, as few CO₂-emitting devices or consumables are used except for employee mobility and SRM.

| Table 2 | Results of case studies incl. scenario for CFP optimisation |
|---------|-----------------------------------------------------------|
| Services | Integrated CFP [kg CO₂e] | Employee mobility | SRM | Sum |
| Cleaning | 7311 | 31.9% | 10.5% | 42.4% |
| Cleaning—scenario for CFP optimisation | 2486 | 42.8% | 10.1% | 52.9% |
| Maintenance | 341 | 62.3% | 17.9% | 80.2% |
| Reception service | 2356 | 69.3% | 26.0% | 95.3% |

**Fig. 1** Comparison of the service CFP for an office building without or incl. employee mobility and SRM
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Digital appliances

Office space

Mobility

Table 3 Optimisation potential in the carbon footprint of SRM (example: cleaning)

| SRM—source of emissions | Cleaning [kg CO$_2$e*a] | Cleaning—scenario for CFP optimisation [kg CO$_2$e*a] | Reduction by [kg CO$_2$e*a] | Share of total reduction: |
|-------------------------|-------------------------|-------------------------------------------------|-----------------------------|---------------------------|
| Office space            | 181.3                   | 20.0                                            | −161.3                     | 66%                       |
| Mobility                | 166.8                   | 83.4                                            | −83.4                      | 34%                       |
| Digital appliances      | 19.0                    | 19.0                                            | 0.0                        | 0%                        |
|                         | 367.1                   | 122.4                                          | −244.7                     |                           |

The approaches to reduce emissions from service-related management mainly concern its mobility and its use of office space. The reduction potentials through energy-efficient electrical equipment are small in comparison, cf. Table 3. The key figures for the services of maintenance and reception correspond to those of cleaning in their distribution across the three areas: office use 49%, mobility 45%, electrical appliances 5%. The mobility of the service-related management offers a service-related optimisation potential to be organised in the case of cleaning of approx. 34% here. The proportionate optimisation potential of the office space used is significantly higher at 66%, but less service-related.

4 Discussion

The relative importance of emissions in service provision due to the mobility of employees and service-related management, as demonstrated by the above case studies, shows the necessity of making these emissions transparent and accounting for them in a form suitable for service optimisation. The accounting at company level, which has been common up to now, is better to overview in its entirety and avoids a proportional allocation of management activities to specific services. However, since the mobility of service employees as well as of service-related management employees is required in each case depending on the specific place of service provision and can also only be significantly changed in coordination with the specific service customers (in the example above: change of operating concept), an allocation of these sources of emissions to the service is conducing to optimisation.

The use of office space accounts for about 45% of the emissions of service-related management. However, their optimisation by renting energy- and space-efficient buildings is not necessarily related to service, especially since only very small amounts of management time are often attributed to service (in the case studies between 0.5% for maintenance and 5% for the object manager in cleaning). The emissions from office use can be reduced by 66% in the case study through measures for energy and space efficiency of the office space (also through desk sharing). But due to the rather weak service reference of the office space use, this can also be dispensed with. In this case, there would also be no need for a procedure to demarcate office use. Another simplification would be that the use of electrical appliances is not included in service-related management. Their share in the emissions of service-related management is only 5%. However, to support these two decisions on simplifying the identification of an integrated service CFP, more case studies and also a broader coverage of other possible services would be important.

The example of a changed operational concept in cleaning shows an additional social benefit that is not made visible by the CFP. Employees are given day jobs instead of part-time work in the evening, which in most cases is more family-friendly and may provide better social security. If one assumes that employees in the service sector take on another activity during the day in addition to the 4 h in the evening, which is again connected with mobility, then the combination into a single day job saves this additional mobility—not only for the environment, but also for the individual. In addition, services that would otherwise be invisible are now connected to visual persons and thus possibly better valued. However, possible disadvantages through disruption of the core business with visible service provision must be considered and mitigated through coordinated control.

The above case studies were modelled in consultation with practitioners from the cleaning, technical and infrastructural services sectors. Similar ratios are found in the analysis of facility services: 11.6 to 25.6% for overheads (in the sense of SRM) and 33.1 to 70.4% for employee mobility. An exception is catering, where operating materials (food) account for a dominant share of the integrated CFP per meal at 92.8% (Pelzeter et al. 2020).

According to the PCR ‘professional cleaning services for buildings’ with specification on hospitals, EPDs can be found that show between 0.377 kg CO$_2$e per m$^2$ (Ducops Service 2017) and 1.27 kg CO$_2$e per m$^2$ (Euro and Promos 2019) and year. These figures include a significantly higher performance level compared to an office property, due to 24/7 operation and the higher hygiene requirements in hospitals. In this respect, the above value of 0.29 kg CO$_2$e per m$^2$ and year for an office property (without employee mobility and SRM) can be classified as basically consistent in dimension. An EPD for cleaning ICE trains (The International
EPD System 2021a) shows a value of 1.28 kg CO₂e per m² and year, comparable to the top value of the indicators for hospitals. Here, a similar classification can be made because of the high intensity of use of an ICE and cleaning at least once a day. However, because the comparison for services other than cleaning and for the inclusion of staff mobility and SRM is missing in these comparative values, the calculations have been described in great detail above to allow for individual verification. A sample Excel file is available as electronic supplementary material.

Another source of uncertainty in the results of the CO₂ estimation for services in the above case studies is that no EPDs were available for many of the products used and instead an estimation was made according to VERUM on the basis of the materials contained in the product. In order to integrate the possibly missing emissions from processing and the end-of-life process, a flat-rate surcharge of 50% was applied to the characteristic values from production. But this may exceed the actual emissions—Berger and Finkbeiner assume that on average about 80% of the emissions of a product result from its manufacture (Berger and Finkbeiner 2017). For the future calculation of the carbon footprint for services, a calculation and not just an estimate must also be made for the products used. As this article aims to estimate the share of emissions not taken into account according to the existing PCR for cleaning, the result is not fundamentally questioned by a partial overestimation of emissions from products used.

The above key figures from existing EPDs are from Italy (hospital cleaning) and Germany (ICE cleaning). The fact that an individual electricity mix with corresponding emissions per kWh is determined for each country further complicates the comparison of the key figures. Countries with high shares of green electricity in the electricity mix, e.g. hydroelectric power like Norway, will have lower emissions per kWh of electricity use (Agora Energiewende and Sandbag 2020). But even with an electricity mix of 37 g CO₂e/kWh (Norway) instead of 408 g CO₂e/kWh (Germany; see Table 7), the share of unaccounted emissions in service provision would not disappear completely. On the one hand, the share of operating materials (including electricity use) in the CFP would also become smaller, and on the other hand, no nation has yet implemented CO₂-free mobility or heating for all users. However, if in the future mobility and the energy supply of buildings are implemented in a completely CO₂-neutral manner, then the expansion of PCRs recommended here to include emissions from employee mobility and SRM will be pointless.

It can be concluded from the case studies that it is necessary to include employee mobility and SRM in the determination of the service CFP. However, the type of integration has only been roughly outlined with the above formulas. This article makes no claim to general validity or practicability. Further research would have to address these questions. For example, the concrete demarcation from general management needs to be detailed. The exemplary modelling of the use of office space can also be refined, e.g. with regard to the question of whether furniture and ancillary rooms, e.g. in the sense of toilets, should also be included proportionately.

Further limitations result from the fact that the mobility indicators are determined without the share of emissions from vehicle production. However, in the author’s modelling (with the assumption of a 12-year service life of the vehicle and approx. 20,000 km of driving per year), these have a share in the total emissions of approx. 10% (6.3% at 40,000 km/a). For electric vehicles, this share increases to about 20% (11.9% at 40,000 km/a). This ambiguity should be addressed in a separate study. The issue was left out here because there is a European standardisation on the subject (European Standards 2012).

Another mobility-related question is the availability of data on employee mobility. The commuting distance and frequency as well as the means of transport of the employees are required here. In the case studies, blanket assumptions were made. The assumption that employees travel approx. 20–30 km commuting distance results from the extent of the city of Berlin, which has a radius of approx. 30 km. For other cities or regions, the commuting distance may be even greater, which would make the above results even clearer.

The definition of public transport as a mix of regional rail, tram and bus could also be further differentiated. The German Federal Environmental Agency has so far only published data for a mix, cf. Tab. 1. Since employees often cannot choose whether to take the bus or the tram—because both are not available as alternatives—optimisation can only start in individual cases with the selection of a certain mode of public transport.

The use and evidence of individual mobility data could pose a data protection problem. In addition, this data is usually not recorded in a structured way so far. However, the interest from a corporate carbon footprint perspective leads to an increased systematic data collection on commuting mobility (Robinson et al. 2018). In practice, this information, which is certainly relevant for work scheduling—who comes from where to the place of work, how and when?—exists, at least as individual background knowledge on the part of service-related management. The abovementioned formula would have to be checked for its data protection concerns and practical applicability and, if necessary, differentiated. The question of how ‘fair-weather cyclists’, occasional e-bike users, etc. are accounted for also needs to be clarified.
5 Conclusions

PCRs for the comparable calculation of the service CFP are hardly available so far. In the two PCRs on cleaning services in hospitals and in ICE trains, it is stated that employee mobility and management activities are not integrated. On the basis of case studies for the services cleaning, maintenance and reception, it could be shown that the emissions of the mobility of the employees and of the activities of the service-related management have a relevant significance compared to emissions of the used equipment and operating materials (e.g. electricity). In relation to the service CFP without the integration, shares between 72% (cleaning services) and 1996% (reception services) are not taken into account in the procedure analogous to the existing PCRs.

In relation to the parameters of the integrated service CFP, employee mobility comprises a share of 31 to 69% and service-related management a share of 10 to 26%. Because optimising the mobility of operational employees and service-related management is particularly effective if it includes changes in the service concept agreed with the service customer (e.g. change from evening to daytime cleaning, jour fixe via video conference), it is recommended to include the mobility arising for the service in the calculation of the service CFP. In this way, the recipient of key figures on the service CFP receives important indications of where optimisation potentials lie in the service concept. If employee mobility were to be shown transparently in the calculation of service CFPs in the future, this environmental aspect of service provision could also be addressed in guidelines for green public procurement (Chiappinelli et al. 2019).

In the case studies, the emissions from the use of office space by service-related management—without optimisation—have a share of approx. 4.5 to 11.7% (related to the integrated service CFP). This means that they have a relevant share in terms of environmental accounting. However, they cannot usually be optimised in a service-related manner. Therefore, their inclusion in the determination of the service CFP can possibly be dispensed with. This question should be discussed amongst experts of LCA with regard to the possibilities of uniform calculation and influenceability of the depicted interrelationships.

Appendix

Table 4 Emissions in public transport (Umweltbundesamt 2021d)

| Means of transport                          | Emissions [g CO₂e/passenger km (Pkm)] |
|---------------------------------------------|----------------------------------------|
| Passenger car                               | 143                                    |
| Aeroplane, domestic                         | 214                                    |
| Rail, long-distance                         | 29                                     |
| Public transport (mix of regional rail, tram and bus) | 55                                     |

Table 5 Emissions in freight transport (Umweltbundesamt 2021c)

| Means of transport | Emissions [g CO₂e/ton km (tkm)] |
|--------------------|----------------------------------|
| Truck              | 113                              |
| Freight railway    | 17                               |
| Inland vessel      | 30                               |

Table 6 Energy use in buildings (Krimmling and Flanderka 2017)

| Operation of office buildings | Low | Medium | High |
|-------------------------------|-----|--------|------|
| Specific energy consumption for electrical energy | 20 kWh/m²a | 30 kWh/m²a | 40 kWh/m²a |
| Specific energy consumption for thermal energy   | 70 kWh/m²a | 80 kWh/m²a | 90 kWh/m²a |

Table 7 Emissions from electricity (Umweltbundesamt 2021b) and heat per kWh (Umweltbundesamt 2021c)

| Energy source | Emissions [kg CO₂e/kWh] |
|---------------|-------------------------|
| German electricity mix | 0.408                   |
| Gas           | 0.215                   |
| Wood pellets  | 0.364                   |

Table 8 Key figures for office equipment

| Digital appliance | kg CO₂e per item | Life span [years] |
|-------------------|------------------|-------------------|
| Desktop PC        | HP 280 Pro G3 Microtower Business, incl. usage | 880 | 5.0 |
| Monitor           | Öko-Institut 2020, incl. usage | 127 | 5.0 |
| Printer           | Related to values from HP | 660 | 5.0 |
| Laptop            | Öko-Institut 2020, incl. usage | 371 | 5.0 |
| Smartphone        | Öko-Institut 2020, incl. usage | 125 | 2.5 |

Key figures for office equipment based on data from the Öko-Institut on the carbon footprint of digital appliances (Gröger 2020) and on data for HP devices (HP 2017)
Table 9  Cleaning incl. employee mobility and service-related management

| CFP            | Total [kg CO₂e] | Relative  | Optimised service | Total [kg CO₂e] | Relative  |
|----------------|-----------------|-----------|-------------------|-----------------|-----------|
| Equipment      | 630.80 kg       | 8.6%      | Equipment         | 617.20 kg       | 24.8%     |
| Operating materials | 3,586.21 kg     | 49.1%     | Operating materials| 55.55 kg       | 22.2%     |
| SRM            | 764.45 kg       | 10.5%     | SRM               | 250.81 kg       | 10.1%     |
| Employee mobility | 2,329.60 kg    | 31.9%     | Employee mobility | 1,064.96 kg     | 42.8%     |
| Service        | 7311.07 kg      | 0.49 kg/m²| Service           | 2485.53 kg      | 0.17 kg/m²|

Share that is not taken into account in the service CFP analogous to the existing PCR: In this example, 3094 kg CO₂e is not taken into account, which would be 72% of the value according to the PCR (see Table 10). In the cleaning scenario optimised for the CFP, 1316 kg CO₂e is not taken into account, or 104%.

Table 10  Cleaning (analogous to the existing PCR)

| CFP            | Total [kg CO₂e] | Relative  | Optimised service | Total [kg CO₂e] | Relative  |
|----------------|-----------------|-----------|-------------------|-----------------|-----------|
| Equipment      | 630.80 kg       | 15.0%     | Equipment         | 617.20 kg       | 52.8%     |
| Operating materials | 3586.21 kg     | 85.0%     | Operating materials| 552.55 kg       | 47.2%     |
| Service        | 4217.02 kg      | 0.28 kg   | Service           | 1169.76 kg      | 0.08 kg/m²|

Table 11  Maintenance incl. employee mobility and service-related management

| CFP             | Total [kg CO₂e] | Relative  |
|-----------------|-----------------|-----------|
| Equipment       | 49.26 kg        | 14.5%     |
| Operating materials | 17.78 kg     | 5.2%      |
| SRM             | 61.19 kg        | 18.0%     |
| Employee mobility | 212.40 kg     | 62.4%     |
| Service         | 340.63 kg       | 0.023 kg/m²|

Share that is not taken into account analogous to the existing PCR: 167 kg CO₂e or 96%, based on the value according to the PCR (see Table 12).

Table 12  Maintenance (analogous to the existing PCR), incl. operational journeys, distance approx. 15 km

| CFP             | Total [kg CO₂e] | Relative |
|-----------------|-----------------|----------|
| Equipment       | 49.26 kg        | 28.4%    |
| Operating materials | 17.78 kg     | 10.3%    |
| Operational journeys | 106.20 kg   | 61.3%    |
| Service         | 173.24 kg       | 0.012 kg/m²|

Table 13  Reception service incl. employee mobility and service-related management

| CFP             | Total [kg CO₂e] | Relative |
|-----------------|-----------------|----------|
| Equipment       | 112.38 kg       | 4.8%     |
| Operating materials | 0.00 kg          | 0.0%    |
| SRM             | 611.91 kg       | 26.0%    |
| Employee mobility | 1.632.00 kg | 69.3%    |
| Service         | 2.356.29 kg     | 0.16 kg/m²|

Share that is not taken into account analogous to the existing PCR: 2244 kg CO₂e or 1996%, based on the value according to the PCR (see Table 14). In other words, the CFP including service-related management and employee mobility—hereinafter referred to as integrated CFP—increases by a factor of 20.

Table 14  Reception service (analogous to the existing PCR)

| CFP             | Total [kg CO₂e] | Relative |
|-----------------|-----------------|----------|
| Equipment       | 112.38 kg       | 100.0%   |
| Operating materials | 0.00 kg          | 0.0%    |
| Service         | 112.38 kg       | 0.007 kg/m² |

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Declarations

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References

Agora Energiewende and Sandbag (2020) The European Power Sector in 2019: Up-to-Date Analysis on the Electricity Transition. https://www.agora-energiewende.de/en/publications/?tx_agorathemen_themenliste%5Bprodukt%5D=1809&cHash=43719f1e81b36512eb854a15dd53be3. Accessed 01 December 2021

Allekotte M et al (2020) Aktualisierung der Modelle TREMOD/TREMOD-MM für die Emissionsberichterstattung 2020. https://www.umweltbundesamt.de/publikationen/aktualisierung-tremod-2019. Accessed 25 June 2021

Apple (2017) iPhone X Environmental Report. https://images.apple.com/environment/pdf/products/iphone/iPhone_X_PER_sept2017.pdf. Accessed 13 April 2002

Bekaroo G, Roopowa D, Zakari A, Niemeier D (2021) Calculating carbon emissions from personal travelling: insights from a top-down analysis of key calculators. Environ Sci Pollut Res Int 7:8853–8872. https://doi.org/10.1007/s11356-020-11179-z

Berger M, Finkbeiner M (2017) Vereinfachte Umweltbewertungen des Umweltbundesamtes (VERUM 2.0). https://www.umweltbundesamt.de/publikationen/vereinfachte-umweltbewertungen-des. Accessed 19 November 2021

Bobba S, Ardente F, Mathieux F (2016) Environmental and economic assessment of durability of energy-using products: method and application to a case-study vacuum cleaner. J Clean Prod:762–776. https://doi.org/10.1016/j.jclepro.2016.07.093

Bundesministerium für Wohnen, Stadtentwicklung und Bauwesen (2022) Ökobaudat. https://www.oekobaudat.de/. Accessed 13 April 2022

### Table 15

| Equipment | Producer | Product type | Equipment CFP | CFP/kg | Number Lifetime | Operating hours/year | Share of use in service [%] | Weight per piece [kg] | Material [CFP/kg] | Distance [km] | Mark-up factor for uncertainty | Material wash subprocess [CFP/kg] | Other material wash subprocess [CFP/kg] | Maintenance [CFP/kg] | Sub-process washing [kg CO2e/a] | Sub-process maintenance [kg CO2e/a] | CFP [kg CO2e/a] |
|-----------|----------|--------------|---------------|--------|-----------------|----------------------|---------------------------|---------------------|----------------|----------------|-------------------------------|-----------------------------|-----------------------------|----------------|---------------------|---------------------|----------------|
| Mop covers | 1.14 | 2 | 20.00 | 100 | 3 | 14.45 | Polyester (PET) | 100 | 5.60 | 2.9 | 1.5 | 1.0 | 1.5 | 1.5 | | | | |
| Dry vacuum cleaner | 28.00 | 100 | 100 | 100 | 3.660 | 1.5 | 14.45 | ABS plastic | 60 | 3.76 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 7.29 | | |
| Cleaning trolley | 177.25 | 10 | 100 | 100 | 0.95 | 1.0 | 0.00 | Falih Eco system | 15 | 2 | 0.00 | 0.00 | 0.00 | 0.00 | | 2.29 | | |
| Work-wear | 22.65 | 7 | 100 | 100 | 0.500 | 1.5 | 1.5 | (EPD) | 500 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | | 9.35 | | |

The International Journal of Life Cycle Assessment (2022) 27:902–915
Burritt RL, Schaltegger S, Zvezdov D (2011) Carbon management accounting: explaining practice in leading German companies. Aust Account Rev 1:80–98. https://doi.org/10.1111/j.1835-2561.2010.00121.x

Carbon-connect AG (2018) Methodik CO2-Bilanzen: MED-COMFORT blue. https://www.carbon-connect.ch/media/filemanager/casestudy/methodik.pdf. Accessed 13 April 2022

Chiappinelli O, Gruner F, Weber G (2019) Green Public Procurement: Climate Provisions in Public Tenders Can Help Reduce German Carbon Emissions. https://www.diw.de/documents/publikationen/73/diw_01.c.071237.de/wdr-19-5-1.pdf. Accessed 06 December 2021

Dadzie J, Runeson G, Ding G (2019) Assessing determinants of sustainable cleaning of existing buildings. JEDT 1:270–292. https://doi.org/10.1080/JEDT-09-2018-0148

Del Borgi A (2013) LCA and communication: environmental product declaration. Int J LCA 2:293–295. https://doi.org/10.1007/s11367-012-0513-9

Dixit MK, Culp CH, Fernandez-Solis JL, Lavy S (2016) Reducing car-

ducos Service (2017) EPD Cleaning service. The International EPD System. https://www.environdec.com/library. Accessed 15 February 2020

EcoForum (2015) Assessment of global warming potential of two textile services. https://www.textile-services.eu/_common/file.cfm?id=AS9ADB6A0F27F7C305D65E31143BB5470. Accessed 13 April 2022

EcoTransIT World Initiative (Ed.) (2019) Ecological Transport Information. https://www.ecotransit.org/download/EcoTransIT_World_Methodology_Data_Update_2019.pdf. Accessed 25 June 2021

Edenhofe O (Ed.) (2014) Climate change 2014. Mitigation of climate change : Working Group III contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, New York, NY. Cambridge Univ. Press (Climate change 2014, contribution to the fifth assessment report of the intergovernmental panel on climate change : Working group 3) Available online at https://www.ipcc.ch/report/ar5/wg3/. Accessed 02 June 2022

Environdec (2022a) Climate declaration for cleaning trolleys. https://portal.environdec.com/api/api/v1/EPDDiary/Files/5212ceb0-d59f-4404-8873-941081293156/Data. Accessed 13 April 2022

Environdec (2022b) Dichiarazione Ambientale Di Prodotto (epd) Di Prodotti Per La Pulizia E L’igiene Di E´Cosí. https://www.environdec.com/api/api/v1/EPDDiary/Files/03939394-c6d9-4824-b479-18838e7b1762/Data. Accessed 13 April 2022

Euro & Promos (2019) EPD Hospital site cleaning system. https://www.environdec.com/library. Accessed 15 February 2020

European Standards (2012) EN 16258 - Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers)

European Union (2013) Commission Regulation (EU) No 666/2013. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32013R0666. Accessed 13 April 2022

Finkbeiner M (2014) The International Standards as the Constitution of Life Cycle Assessment: The ISO 14040 Series and its Offspring. In: Klöpfer W (ed) Background and Future Prospects in Life Cycle Assessment. Springer Netherlands, Dordrecht, pp 85–106. https://doi.org/10.1007/978-94-017-8697-3_3

Franchetti MJ, Apul D (2012) Carbon footprint analysis. CRC Press/Taylor & Francis Group, Boca Raton, FL

Frischknecht R (2020) Lehrbuch der Ökobilanzierung. Springer Berlin Heidelberg; Imprint: Springer Spektrum, Berlin, Heidelberg

Garcia R, Freire F (2014) Carbon footprint of particleboard: a comparison between ISO/TS 14067, GHG Protocol, PAS 2050 and Climate Declaration. J Clean Prod:199–209. https://doi.org/10.1016/j.jclepro.2013.11.073

German Facility Management Association e.V (2021) GEFMA 162–1 Carbon Management von Facility Services, Bonn

Riboss D, Schaltegger S (2015) Carbon management accounting and reporting in practice. Sustain Account Manag Policy J 3:340–365. https://doi.org/10.1108/SAMPJ-02-2015-0014

Gluszak G, Zielba M (2019) Smart and green buildings features in the decision-making hierarchy of office space tenants: an analytic hierarchy process study. Adm Sci 3:52. https://doi.org/10.3390/admsci9030052

Grüger J (2020) Digitaler CO2-Fußabdruck. https://www.oeko.de/publikationen/p-details/digitaler-co2-fussabdruck. Accessed 28 June 2021 (Appendix)

Hertwich EG, Wood R (2018) The growing importance of scope 3 greenhouse gas emissions from industry. Environ Res Lett 10:40103. https://doi.org/10.1088/1748-9326/aae19a

HP (2017) Product Carbon Footprint - Desktop Available online at https://h22235.www2.hp.com/hpinfo/globalcitizenship/environment/productdata/Countries/ _MultiCountry/productcarbonfootprint_
deskt_201710322125574.pdf. Accessed 10 December 2021 (Appendix)

ifeu (Ed.) (2021) Berechnungstools. Institut für Energie- und Umweltforschung Heidelberg. https://www.ifeu.de/methoden-tools/ berechnungstools/. Accessed 14 July 2021

ISO (2006) ISO 14025 - Environmental labels and declarations - Type III environmental declarations - Principles and procedures, Geneva

ISO (2018) ISO 14067 - Greenhouse gases - Carbon Footprint of Products - Requirements and guidelines for quantification, Geneva

ISO (2019) ISO 14044 - Environmental management - Life cycle assessment - Requirements and guidelines, Geneva

ISO (2020) ISO 14040. Environmental management - Life cycle assessment - Principles and framework, Geneva

Kartner J et al (2019) Health Care´s Climate Footprint. http://www. arup.com/perspectives/publications/research/section/healthcare-climate-footprint. Accessed 01 July 2021

Klaassen L, Stoll C (2020) Harmonizing corporate carbon footprints. Technical University Munich, Massachusetts Institute of Technology

Krämer M, May M, Pelzeter A (2021) CarbonFM. https://carbonfm. de/. Accessed 02 September 2021

Kriemling J, Flanderka O (2017) Energiebedarf von Bürogebäuden. Fraunhofer IRB Verlag, Stuttgart

Kronborg Jensen J (2012) Product carbon footprint developments and gaps. Int Jnl Distri & Log Manage 4:338–354. https://doi.org/10.1108/09600031211231326

Lawn PA (2016) Resolving the climate change crisis. Springer, Dordrecht

Mediamarkt (2022) ROWENTA SILENCE FORCE 4A++ Staubsauger, maximale Leistung: 400 Watt, Blau. https://www.mediamarkt. de/product/rowenta-silence-force-4a-staubsauger-maximale-92353701.html. Accessed 13 April 2022

Mosadeghrad AM (2013) Healthcare service quality: towards a broad definition. Int J Health Care Qual Assur 3:203–219. https://doi. org/10.1108/09526681311311409

Nansai K, Fry J, Malik A, Takayanagi W, Kondo N (2020) Carbon foot-
