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Greenhouse gas emissions of an outpatient care service: a cost-based approach

Treibhausgasemissionen eines ambulanten Pflegedienstes: ein kostenbasierter Ansatz

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Keywords:
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A B S T R A C T

Introduction: Climate change is already having an impact on global health and will continue to do so even more. Heat waves and extreme weather events are only part of the impact. Adapting health services to these threats is only partially possible, so another focus should be on mitigating climate change by minimising greenhouse gas emissions. In this context, health care can play an important role. However, evidence about greenhouse gas emission hotspots and alternative action to mitigate greenhouse gas emissions is needed for the shift to a climate-friendly health system.
Methods: In this paper, the greenhouse gas emissions of an outpatient care service will be calculated. On the one hand, focal points of the emissions will be identified and the effects of climate-friendly measures calculated. In order to calculate a comprehensive footprint, a hybrid approach was chosen in which emissions from electricity, gas and fuels are determined on the basis of quantities, and emissions resulting from the production of consumer goods are calculated using cost-based emission factors. The expenditure and consumption data required come from a care service in Lower Saxony providing for 132 people in need of care.
Results: The outpatient care service emitted a total of 37,258 kg CO_2eq in 2018, i. e. roughly 282 kg CO_2eq per year and person in need of care. The production (15 %) and combustion of fuels (68 %) accounted for the largest share of 73 %. By switching to diesel vehicles, the care service could save 7 % of the annual greenhouse gas emissions and by switching to electric vehicles up to 30 %.
Discussion: The study shows that the outpatient care service produces greenhouse gas emissions of about 282 kg CO_2eq per year and person in need of care, which is a relevant amount given the average per capita emission of 7.9 kg CO_2 in Germany. However, these emissions can be reduced by more than half by making the relatively easy switch to electric cars.

Limitations of the study relate to potential inaccuracies of the cost-based emission factors and the lack of information about the kilometers driven and the fuel consumed.
Conclusion: The majority of the emissions of an ambulatory care service comes from the production and combustion of fuels. However, this source can be significantly reduced by switching to modern technologies. To validate the results of this study, further studies should be conducted, preferably with a bottom-up methodology.

Z U S A M M E N F A S S U N G

Hintergrund: Der Klimawandel hat bereits und wird auch in Zukunft zunehmend Einfluss auf die globale Gesundheit haben. Hitzewellen und Extremwetterereignisse sind nur ein Teil der Auswirkungen. Eine Anpassung der Gesundheitsversorgung an diese Gefahren ist nur in Teilen möglich, sodass ein weiterer Schwerpunkt auf der Abschwächung des Klimawandels liegen sollte, indem der Ausstoß von Treibhausgasen minimiert wird. Eine wichtige Rolle kann hier die Gesundheitsversorgung spielen. Aber

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für die Transformation zu einer klimafreundlichen Gesundheitsversorgung braucht es Evidenz über Treibhausgasemissionshotspots und Handlungsalternativen zur Reduktion der Emissionen.

Methode: In dieser Arbeit sollen die Treibhausgasemissionen eines ambulanten Pflegedienstes berechnet werden. Dabei sollen zum einen Schwerpunkte der Emissionen identifiziert und die Auswirkungen klimafreundlicher Maßnahmen berechnet werden. Um einen umfassenden Fußabdruck zu berechnen, wurde ein hybrider Ansatz gewählt, bei dem die Emissionen durch Strom, Gas und Kraftstoffe anhand der Mengen und die Emissionen, die durch die Produktion von Verbrauchsgütern entstehen, durch kostenbasierte Emissionsfaktoren berechnet werden. Die benötigten Ausgabe- und Verbrauchsdaten stammen aus einem niedersächsischen Pflegedienst mit 132 Pflegebedürftigen.

Ergebnisse: Der ambulante Pflegedienst hat im Jahr 2018 insgesamt 37.258 kg CO_2eq ausgestoßen, d. h. gut 282 kg CO_2eq pro pflegebedürftige Person. Der größte Anteil mit 73 % entfiel dabei auf die Produktion (15 %) und das Verbrennen von Kraftstoff (68 %). Durch die Umstellung auf Dieselfahrzeuge könnte der Pflegedienst 7 % seines jährlichen Treibhausgasaustoßes einsparen, durch die Umstellung auf Elektrofahrzeuge bis zu 30 %.

Diskussion: Die Studie konnte zeigen, dass der ambulante Pflegedienst Treibhausgasemissionen von 282,26 kg CO_2eq pro pflegebedürftiger Person verursacht, was bei einem durchschnittlichen Pro-Kopf-Ausstoß von 7,9 kg CO_2 in Deutschland einer relevanten Menge entspricht. Dieser Ausstoß kann jedoch durch die relativ leichte Umstellung auf E-Autos um mehr als die Hälfte gesenkt werden.

Limitationen der Studie beziehen sich insbesondere auf die möglichen Ungenauigkeiten der kostenbasierten Emissionsfaktoren und die fehlende Information über gefahrene Kilometer bzw. verbrauchten Treibstoff.

Schlussfolgerung: Der Großteil der Emissionen eines ambulanten Pflegedienstes entsteht durch die Produktion und Verbrennung von Kraftstoffen. Diese Quelle kann jedoch durch Einsatz moderner Technologien signifikant gesenkt werden. Um die Ergebnisse dieser Studie zu validieren, sollten weitere Studien, vorzugweise mit einer Bottom-up-Methodik, durchgeführt werden.

Schlüsselwörter:
Treibhausgasemissionen
Ambulanter Pflegedienst
CO_2-Fußabdruck

Introduction

Humans are mainly responsible for global warming of about 1 °C compared to pre-industrial times (1850–1900) and continue to cause an increase by 0.1 °C to 0.3 °C per decade [1]. In particular, the greenhouse gases (GHGs), such as carbon dioxide (CO_2), methane and CH4, are held responsible for anthropogenic, i.e. man-made, climate change [2]. It is common to use CO_2-equivalents (CO_2eq) as the unit of measurement of GHG impacts on the climate. CO_2eq summarizes the radiative forcing (i.e. the effect responsible for global warming) of the various GHGs on global warming in one value. For example one kilogram of methane, has the same impact on global warming as 27.2 kg of carbon dioxide [3].

The rise in global temperatures has a clear impact on human health. For example, temperature-related mortality is rising [4]. The World Health Organization(WHO) projects 241 000 additional deaths from heat-related causes, diarrheal diseases, malaria, dengue fever, flooding and child malnutrition in 2030 due to climate change, and a further 250 000 deaths per year between 2030 and 2050 [5]. For western Europe, especially Germany, the climate change will lead to higher death rates due to heat waves connected with an aging population, higher rates in allergic reaction due to immigration, spread and proliferation of neophytes, and spread of vectors, such as the Asian tiger mosquito [6]. For the sake of the general health of humanity, greenhouse gas emissions and thus anthropogenic climate change should be mitigated [4].

Globally, two gigatonnes of CO_2 and thus 4.4% of GHG emissions are attributed to the health sector [7]. The contribution of the health sector to climate change is particularly large in high-income countries. Within the OECD, the share of CO_2 emissions from the health sector in total emissions rises to 5.5% [6], with even larger proportions in countries such as Germany (6.7%), Austria (6.7%) or Switzerland (5.9%) [6]. Without climate action, absolute global emissions from the healthcare sector will more than triple by 2050 compared to 2014, reaching six gigatonnes per year [8], so change in this sector is essential. Outpatient care is an important and growing sector in healthcare. 14 700 outpatient care provider and 982 000 patients were registered in Germany in 2019, growing from 12 000 provider and 616 000 patients in the year 2009 [9]. As the outpatient care sector is growing it should identify mitigation potentials in order to contribute to the overall efforts for a climate-neutral health care sector.

A first step towards reducing greenhouse gas emissions is to evaluate its own carbon emissions and identify hotspots, i.e. areas with relatively high emissions and associated opportunities for savings. Hotspot analysis on an institutional level can help identify possible solutions and help decision makers to reduce the GHG emissions from their company. For a comprehensive view and to avoid blind spots in the analysis a life cycle perspective should be taken into account. This means that not only direct emissions from the burning of fuels as well as indirect emissions from electricity consumption are measured, but also emissions that occur in upstream and downstream processes [10]. To calculate organisational greenhouse gas emissions, the Greenhouse Gas Protocol has become one of the common standards. The GHG protocol provides a structure of emission sources to analyse organizational GHG emissions. The emissions are divided into three scopes (Scope 1, 2 and 3) [11]. Scope 1 describes direct emissions. Direct emissions include greenhouse gases released from sources controlled by the company. These include, for example, emissions from the combustion of heating fuels (fuel oil, gas, etc.) or emissions from the combustion of fuels in vehicles [11]. Scope 2 refers to indirect emissions from the production of electricity. These emissions are indirect, because they emerge outside of the direct control of the company [11]. Scope 3 includes the indirect emissions that arise in upstream and downstream processes [11]. Indirect emissions from electricity generation is already included in Scope 2, therefore they are excluded from Scope 3 to prevent double counting. Examples of Scope 3 are the production of goods which are used by the company or waste treatment.

One way to measure comprehensive GHG emissions of institutions and companies is based on hybrid input-output models [10]. This methodology combines volume-based and cost-based emission factors. Emissions of Scopes 1 and 2 are calculated based on quantities and the specific emission factors. For example, the amount of natural gas used is multiplied by the specific GHG emissions generated by burning the gas. Scope 3 emissions can be determined using cost-based emission factors and expenditure data. Cost-based emission factors are derived from environmentally extended input-output tables and indicate the emissions per monetary unit produced for individual industrial sectors (e.g. kg CO_2eq / €).

Input-output tables indicate the interconnectedness of economic and industrial sectors in monetary units. The columns of the input-output matrix show the inputs to the respective sector that were brought in by the other sectors during the period, i.e. the input into that sector. The rows show the outputs of the respective sectors, on the one hand in the form of intermediate products in other industrial sectors for the production of further goods or as finished goods to the final demand by consumers or the public sector, i.e. the output of that sector. With the help of matrix algebra, these matrices can be converted, so these values refer to production in the value of one monetary unit. Thus, the inputs indicate how much input is needed to produce goods worth one monetary unit in the respective sector. The output lines indicate how the produced good in the value of one monetary unit is distributed among the other sectors and the final demand. Through further calculations, the Leontief inverse can be created. The inverse shows the input and output of the entire supply chain needed to produce a good in the respective sector. For example, when looking at the production of wearing apparel, the Leontief inverse shows the needed input from raw materials such as cotton, as well as intermediate production such producing the textiles from said cotton. The Input-Output table can be extended by emission factors so that for each sector an emission factor is given on how much GHGs are emitted when goods with a value of one monetary unit are produced. Combining the Leontief inverse with the emission factors, the emissions can be calculated that arise over the entire production and supply chain when goods with a value of one monetary unit are produced by the sector under consideration. This results in the above-mentioned emission factors of, for example, kg CO_2eq/€. One disadvantage of the method is possible inaccuracies. These arise on the one hand from the top-down approach, whereby only average values of industry sectors and their supply chains are used, and on the other hand from being based on monetary units, whereby the actual material consumption is only estimated. An alternative to cost-based methods is the use of process-based data of individual goods. Although this promises greater accuracy due to a bottom-up approach, there is a lack of data, especially in the healthcare sector. In addition, the creation of such process-based modelling is very time consuming, especially for larger units such as companies. Previous work on GHG emissions in the health sector mostly refers to medical care provided by hospitals or outpatient services (e.g. general practitioners). For example, Prasad et al. [12] calculated the ecological impact of inpatient care in a New York hospital . The calculations are based on building management data and systematic waste collection. A similar method was used by MacNeill et al. [13] to calculate GHG emissions from operating theatres in three different countries. Cost-based calculations of indirect emissions can be found, among others, in Duane et al. [14], who calculate GHG emissions from dental treatments in Scotland, and Tenisson et al. [15], analysing the GHG footprint of the NHS public health system.

To our knowledge, there is no study that determines the GHG emissions of outpatient care services. The aim of this paper is therefore to fill this gap and to calculate a cost-based GHG footprint using an outpatient care service from Lower Saxony as an example and to assess possible effects of mitigation actions.

Material and method

Method

Scope 1

To calculate the emissions from natural gas consumption in the service's administration building, the amount of gas in kWh was multiplied by the available emission factor. According to the Federal Ministry of Transport and Digital Infrastructure one kWh of natural gas emits 202g CO_2eq during combustion [16].

According to information from the care service, all passenger cars are fueled with petrol. Since no quantity-based accounting for fuel consumption was available, this quantity had to be calculated using the refueling costs and the average fuel prices for 2018. For detailed calculation description see the appendix.

Scope 2

The emissions from the provision of electricity were calculated on the basis of the reported consumption and the emission factor for the average electricity mix in Germany for 2018. According to the European Environmental Agency, the production of one kWh electricity emits 404g $CO2_2$eq [17] and 2562.65 kWh electricity was used by the care service.

Scope 3

To calculate indirect emissions (excluding electricity production) expenditure data provided by the outpatient care service is multiplied by cost-based emission factors. It should be noted that expenditure on petrol and gas is also used, as Scope 1 only measures emissions during combustion, but not the emissions that arise during the production and provision of the energy sources. Cost-based emission factors were taken from the Eurostat's air emissions intensities data base [18].

To calculate emissions, the expenditure accounts must be linked to appropriate sectors for which cost-based emission factors are available. The link between expenditure accounts and sectors and the exact calculation of emissions is documented in the appendix.

Data

The outpatient care service considered in this paper is based in Lower Saxony, is privately run and cared for 132 people in need of care in 2018. A mixed form of care consisting of care and nursing services is offered. The fleet of the care service consists of four Opel Corsa, one Opel Zafira and one Mini.

For the calculation of CO_2 emissions, both the G/L accounts from the 2018 annual financial statements and supplementary data on electricity and gas consumption were included. In total, 260 financial postings from 23 accounts were included, amounting to a total of €41,650.62.Due to accounting periods deviating from the annual financial statement, the data of electricity and gas consumption originate from the period from April 2018 to April 2019. We assume that the gas and electricity consumption from this period is identical to the period from 1^{st} January to 31th December 2018, i.e. the period, that is described by the financial data and acts as a reference year of the investigation.

The sources of the emission factorsare listed in Table 1. In addition to CO_2, the greenhouse gases nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). Detailed calculations can be found in Appendix A.

Results

In 2018, the care service emitted a total of roughly 37 258 kg CO_2eq. This corresponds to a GHG footprint of 282 kg CO_2eq per year and per person in need of care. The largest source of GHGs is the emissions from burning petrol (69%) and the upstream processes to provide the petrol (18%). Together with the emissions from natural gas consumption, the Scope 1 emissions amount to 27 755 kg CO_2eq or 74 % of the total emissions. Scope 3 emissions amount to around 8 468 kg CO_2eq or 23 % of total emissions and

Table 1
Summary of emission factors and sources.

Scope und emission source	Source of emission factors	Emission factors
Scope 1: Gas	Federal Ministry of Transport and Digital Infrastructure [16]	0.202 kg CO_2e / kWh
Scope 1: Fuel	Federal Ministry of Transport and Digital Infrastructure [16]	Tank-to-Wheel 2.42 kg CO_2e / L
Scope 2: Electricity (2018)	European Environmental Agency [17]	0.404 kg CO_2e / kWH
Scope 3: Indirect emissions excl. electricity	Eurostat [18]	Cost-based emission factors for 78 industrial and economical sectors

Scope 2 emissions amount to 1 035 kg CO_2eq or 3 % of total emissions. Figure 1 shows the share per emission source, whereby the Scope 3 emissions were divided into the provision of petrol and other emissions. The individual sources under “other emissions” each have less than a 1% share of total emissions.

Scenario analysis

In order to evaluate the possibilities of the care service to reduce its GHG footprint, different scenarios were used and the savings calculated. As the provision and consumption of fuel for the car fleet accounts for more than 85%, the scenarios refer to this emission source. In scenario 1, petrol cars are replaced by diesel engines. In scenario 2 by electric vehicles (EV). To calculate the emissions of the two scenarios, the petrol consumption was converted into kilometers driven. For this purpose, an Opel Corsa 1.2 was assumed, as well as the manufacturer’s data on consumption per 100 km. For the scenarios, comparable passenger cars were assumed and the manufacturer’s specifications were used. For Scenario 2 the differences in GHG emissions of the production of the vehicles have been included. Results from Hawkins et al. show production emissions for EV between 87 g CO_2eq/km and

95 gCO_2eq/km and production emissions from internal combustion vehicles at 43 CO_2eq/km [19]. We assumed a lifespan of 10 years per vehicle. Specific calculation steps can be seen in the Appendix. The results are shown in Figure 2.

If the care service were to replace its car fleet with diesel cars, it could reduce GHG emissions by 2 592 kg CO_2eq, a saving of nearly20 kg CO_2eq per year and per person in need of care, or 7%. If the fleet is replaced by EV, 25 657 kg CO_2eq Scope 1 emissions are replaced by 12 374 kg CO_2eq Scope 2 emissions, and 6 640 kg CO_2eq Scope 3 emissions can be saved as the upstream steps to produce the petrol are eliminated. Between 8 639 kg CO_2eq and 10 210 kg CO_2eq are added due to additional production emissions of EV. This corresponds to a total reduction of 9 715 kg CO_2eq–11 285kg CO_2eq or 74 kg CO_2eq–85kg CO_2eq per year and per person in need of care, or 26%–30% of total emissions.

Discussion

Compared to the distribution of emissions of the entire German health care system, the figures of the outpatient care service differ significantly in some cases. Scope 1 emissions account for a share of 74 % for the care service, a significantly higher share than for the entire health system, where they only account for a share of 16 % [20]. The shares of Scope 2 and Scope 3 emissions in the total emissions of the care service are comparatively smaller. Scope 2 emissions with a share of 3% compared to 18%. [20] and Scope 3 emissions with a share of 23 % compared to 66 % in the entire health system [20]. General measures to reduce the GHG emissions of the health system, such as the use of renewable electricity sources or investments in buildings, can therefore only be adopted to a limited extent. If instead the main source of emissions, the supply and combustion of petrol, is seen as a potential, 7% of emissions can be saved by switching to diesel vehicles and up to 30% by switching to EV. Further savings could be realised by switching to “green” electricity, as in scenario 2 twelve tonnes CO_2eq would be emitted by the electricity generation for the car fleet.

Limitations

This work has some limitations due to the method used and the data used. One limitation of the calculation using cost-based emission factors is that they are based on monetary units. Often, ecologically produced products cost more money because low-emission production is more expensive or higher-quality materials are used. However, using cost-based emission factors, one would calculate higher emissions for the products than for conventionally produced and cheaper goods. Since the care service has not used ecolo-

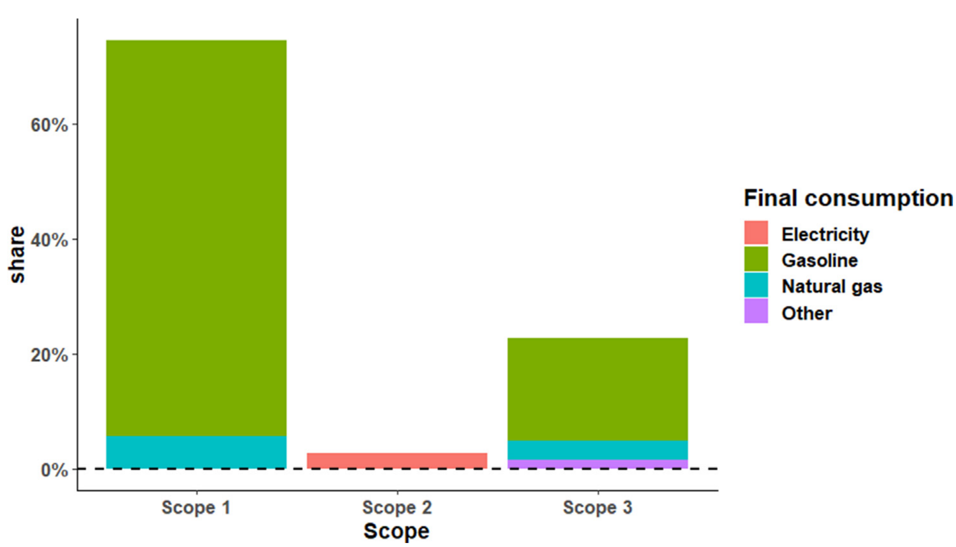

Figure 1. Breakdown of emissions by scope and by end use.

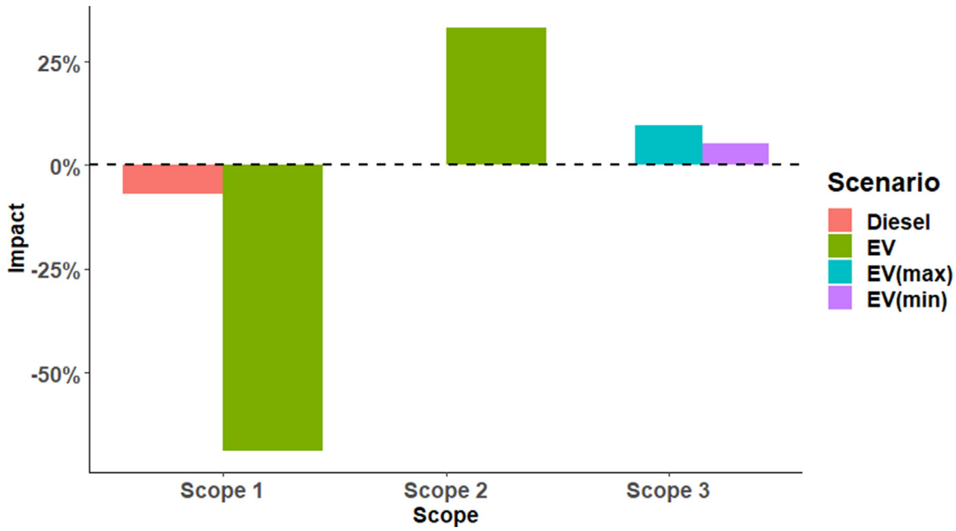

Figure 2. GHG savings potential by using diesel engines or e-cars instead of petrol.

gically produced goods to any particular extent so far, it can be assumed that this bias is limited. Another limitation of the cost-based emission factors is that they are based on input-output data consisting of aggregated industrial sectors and only form average values for these sectors. For example, the production of petrol and diesel in Scenario 1 is assigned to the sector "*Manufacture of coke and refined petroleum products*" and are identical. If process-based data are used, it can be seen that the well-to-tank emissions, i.e. the emissions that occur during the production of the fuel, differ between petrol and diesel [16].

Since some of the data used was aggregated into accounts, it was no longer possible to trace the materials in the office supplies account, which could have led to inaccuracies. The biggest limitation from the data used is that the consumption of fuel for the car fleet was only available in cost form and not as a quantity figure. This meant that consumption had to be converted using average costs, which might resulted in some inaccuracies. In addition, it was assumed that the kilometer allowance paid to the employees in the amount of 30 cents per kilometer covered the amount of the petrol costs and that the employees made these journeys by car. Even greater inaccuracies result for the scenario calculations for diesel cars and electric cars, as the amount of petrol consumed was converted into kilometers driven with the help of consumption data, which was then converted back into fuel or electricity consumption for the respective scenario. This procedure allows for many distortions (e.g. by using consumption data from the manufacturer) and inaccuracies. Therefore, these results should be used as an orientation for possible savings measures.

Conclusion and outlook

Using a hybrid model based on consumption data for electricity and natural gas and cost data from the annual financial statements, the emissions of an outpatient care service were calculated for 2018. All three scopes were considered. The total emissions amount to 37 258 kg CO_2eq or roughly 282 kg CO_2eq per year and per person in need of care. The majority of the emissions resulted from the burning of petrol (69%) and the upstream processes to produce the petrol (18%). A smaller amount of GHG emissions could be saved by using diesel cars (7%), while larger savings could be created by using electric cars (53%). The work has shown that the comprehensive calculation of the GHG footprint based on cost and consumption data is possible and thus includes emissions from upstream production processes. The results can provide insights into emission hotspots and possibilities for reducing GHG emissions, especially for operators of care services, as well as the possibility to calculate their own emissions. In order to confirm, expand and make the results and lessons learned more robust, they should be validated through further studies, with car consumption data collected in volume terms. Further studies and data would also help operators to find appropriate comparative data and opportunities to reduce GHG emissions.

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Conflict of Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Leona Grün advised the outpatient care service between the years 2020 and 2021 with regard to applying for funding.

CRediT author statement

Mattis Keil: Conceptualization, Validation, Investigation Writing - Review & Editing, Visualization, Supervision
Leona Grün: Methodology, Investigation, Data Curation, Writing - Original Draft

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.zefq.2022.09.005.

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