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Review Paper

CARBON ACCOUNTING IN THE PUBLIC SECTOR – CHALLENGES, APPROACHES AND PERSPECTIVES FOR MUNICIPALITIES

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Abstract. *Nowadays, combating climate change and its effects due to the anthropogenic greenhouse effect is one of the central challenges for society and politics in order to prevent further increase of greenhouse gases in the atmosphere and thus become climate neutral. An indispensable prerequisite for the selection, implementation and monitoring of the effectiveness of measures to reduce greenhouse gas emissions is the measurement and accounting of emissions through the implementation of a carbon accounting system. Compared to companies, the topic of carbon accounting at the municipality level has so far received less public attention. Therefore, this paper deals with the specific challenges, the approaches and the perspectives of municipal carbon accounting.*

Key words: *carbon accounting, greenhouse gas emissions, municipalities, climate changes*

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1. INTRODUCTION

Sustainability and sustainable development in general, as well climate protection in particular, are among the dominant issues of the 21st century. According to one of the oldest and most common definitions of sustainability, „sustainable development aims to ensure that the needs of the present are met without risking that future generations will not be able to meet their own needs" (UN, 1987, Chapter I 3 No. 27, p 15). The importance of the issue and its broad scope imply that sustainable development should be approached internationally. In September 2015, the United Nations (UN) member states adopted the Agenda 2030 (UN, 2015a). At the heart of the Agenda are the 17 Sustainable Development Goals (SDGs), which are further divided into 169 sub-goals (Lorson & Haustein, 2022). The municipality level is explicitly considered in the SDGs, with SDG 11 stating that cities and settlements should be made inclusive, safe, resilient and sustainable. Measures for climate protection can be found in SDG 13 (Koch et al., 2019). The main cause of climate changes is the human-induced greenhouse effect: human activities, such as the burning of fossil fuels, cause an increase in greenhouse gases in the atmosphere, leading to a steady global warming and ultimately to the problems of rising sea levels, increasing frequency of extreme weather, droughts and generally negative consequences for biodiversity and ecosystems.

The UN Framework Convention on Climate Change (UNFCCC) is considered to be the origin of international climate policy (UN, 1992, UNFCCC). It was signed by 154 countries at the United Nations Conference on Environment and Development in Rio de Janeiro in 1992. By ratifying the convention, the industrialized countries undertake to continuously account for their greenhouse gases (GHG) and to report annually in an inventory, the National Emissions Inventory. This is because the key to limiting climate changes lies in reducing GHG emissions to the point of complete GHG neutrality. GHG neutrality or climate neutrality describes the state in which no net contribution to the concentration of greenhouse gases in the atmosphere is made, i.e. any emissions are either avoided or compensated. If this consideration refers only to the specific greenhouse gas CO2, this is referred to as CO2 neutrality (Butler et al., 2015). In addition, a climate conference (Conference of the Parties, COP) has been held annually since 1992. A groundbreaking conference took place in Kyoto in 1997 (COP3) with the adoption of the Kyoto Protocol (UN, 1998). This set limits on GHG emissions for the first time. At the 2015 conference in Paris (COP21), the Paris Agreement (UN, 2015b) was reached, replacing the Kyoto Protocol, which expired in 2020, and committing its participants to limit global warming to well below 2°C and preferably to 1.5°C above pre-industrial levels. In December 2019, the European Green New Deal (European Commission, 2019) was unveiled, making Europe the first continent to become GHG neutral by 2050.

Increasingly, science and politics are warning that current efforts in the climate crisis fall far short of what is needed to curb the human-induced rise in temperature. This is clear from the current Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), in which the IPCC assesses the global residual CO_2 budget from the beginning of 2020 at around 400 gigatons, compliance with which will enable the 1.5 °C target to be achieved with a probability of 67% (IPCC, 2021).

2. Fundamentals of Carbon Accounting

As an indispensable prerequisite for GHG mitigation measures, carbon accounting leads to a GHG balance sheet or inventory through the measurement and reporting of emissions (Brohé, 2016). In this context, the term carbon footprint is often used. The fundamental issue here is which greenhouse gases are to be recorded. Natural and anthropogenic greenhouse gases account for less than 1% of the components of the atmosphere, since their main components, measured by volume fraction, are nitrogen at 78.08% and oxygen at 20.94% (Bridgman, 2005). Important natural greenhouse gases are hydrogen, carbon dioxide (CO_2), methane (CH_4), ozone and nitrous oxide (N_2O). In addition, there are fluorinated greenhouse gases, so-called F-gases, which are exclusively caused by humans (Brohé, 2016). Hydrogen or ozone occur in large quantities, but unlike the other greenhouse gases, they play only a minor role in the anthropogenic greenhouse effect. The political targets for greenhouse gas reduction are based on the Kyoto Protocol of 1997. This initially anchored six greenhouse gases to be documented: carbon dioxide, methane, nitrous oxide, hydrofluorocarbons (HFCs/HFCs), perfluorocarbons (HFCs/PFCs) and sulfur hexafluoride (SF_6) (Chang & Bellassen, 2015). At the 18th UN Climate Change Conference in Doha in 2012, the harmful gas nitrogen trifluoride (NF_3) was added to the list for the upcoming second period of the Kyoto Protocol (UN, 2012). Consequently, the accounting should, as far as possible, not only take into account CO_2 or carbon compounds, as the term "carbon accounting" might suggest, but also the other relevant greenhouse gases.

In order to determine a total quantity of GHG emissions, the values of all greenhouse gases considered in the balance must first be converted into a common unit (Brohé, 2016): Since CO_2 has the greatest significance for the anthropogenic greenhouse effect, this gas is used as the reference value. All greenhouse gases are converted into CO_2 equivalents (CO_2e) according to their relative Global Warming Potential (GWP). The GWP_N is the ratio of the contribution of a specific gas to the greenhouse effect over a given period N to the corresponding contribution of CO_2. Current calculations of CO_2 equivalents are regularly based on the determined GWP of the IPCC. CH_4, for example, has a GWP_{100} of 28 and thus 28 times the effect of CO_2 over the period of 100 years (UBA, 2020).

In detail, the calculation is technically complex and offers room for discussion at many points. For example, in order to prepare a GHG balance, the so-called inventory boundaries must be defined in order to delimit for which subsystem, for which geographical area and for which time period the effects are to be recorded. The issues of completeness and responsible allocation of GHG emissions are also much discussed, with two different approaches to accounting. According to production-based accounting (territorial accounting), all emissions that are emitted within the spatial boundary of a considered territory are included in the balance. Emissions from the export of locally produced goods are included, while emissions related to imported goods are excluded (Peters, 2008). In contrast, consumption-based accounting includes all emissions caused by all consumption within the territory under consideration, even if they are emitted outside the territory. The choice of methodology undoubtedly has important implications for the level of GHG emissions identified (Hoornweg et al., 2011). Territorial accounting is the predominant approach in practice and is also the subject of national emissions inventories to be prepared under the UNFCCC, which follow the IPCC accounting rules (IPCC, 2006).

3. The Role of municipalities in climate change

Due to increasing urbanization and the associated energy consumption and CO_2 emissions, municipalities are contributing their share to climate change. At the same time, the negative effects of climate change are directly felt in cities through extreme weather events, such as flooding caused by heavy rainfall, water shortages, heat waves, or changes in the microclimate and the creation of heat islands (Cutter et al., 2012; WBGU, 2016). This proximity to the problem also results in proximity to the solution, providing good reasons for climate protection efforts and ultimately for carbon accounting in municipalities. Through politically close contact with citizens, municipalities can mediate between different interests, promote citizen participation and increase the acceptance of measures (DIFU, 2018).

To take advantage of opportunities to share information and scale activities, municipalities can also form networks internationally; among the largest are the Climate Alliance, with 1,915 members from 27 mostly European countries (Climate Alliance, 2022), and the Global Covenant of Mayors for Climate & Energy (GCoM), with approximately 12,500 cities (GCOM, 2022) representing over one billion people, nearly one-eighth of the world's population.

3.1. Approaches to the design of carbon accounting at the municipal level

With the growth of climate protection as a separate municipal area of responsibility, the first local energy supply concepts were developed in the 1980s and 1990s, specifically including measures for the economical use of energy (Blümling, 2000; Müschen, 1998). Internationally, there was no leading carbon accounting standard at the municipal level for a long time. Instead, many independent attempts existed to design a suitable approach, which meant that the comparability of GHG balances suffered (for example Hillman & Ramaswami, 2010; Sovacool & Brown, 2010).

It should be noted that the GHG accounting of municipalities is not limited to the activities of the central administrative unit or the accounting of municipal enterprises, but includes all activities in the geographical area of a municipality.

In the following, an international standard for GHG accounting will be presented.

3.2. Global Protocol for Community-Scale Greenhouse Gas Inventories

Since 2014, the Global Protocol for Community-Scale Greenhouse Gas Inventories (GPC) has been an internationally recognized and practiced accounting standard, revised in 2021 as version 1.1. It is an adaptation of the GHG Protocol Corporate Standard developed for companies to the community level. It was developed by three organizations, the World Resource Institute (WRI), the C40 Cities Climate Leadership Group and ICLEI - Local Governments for Sustainability, in cooperation. The GPC standard aims to provide assistance in preparing a comprehensive GHG balance sheet to support municipal climate protection planning.

The GPC standard consists of three parts and a likewise three-part appendix with supplementary information. Part 1 describes the basic requirements for accounting, in addition to an introduction to the development and purpose of the GPC. Part 2 contains the specific guidelines for calculating GHG emissions, since for the majority of activities emissions cannot be measured directly and therefore must be estimated using activity data and emission factors (e.g., using the IPCC's Emission Factor Database (EFDB)).

Finally, Part 3 deals with GHG emissions mitigation goal setting and monitoring the implementation of these goals. Furthermore, it deals with the management of the quality of GHG balances and the possible verification.

3.2.1. Accounting in accordance with the GPC standard

A city's GHG inventory should follow the general accounting principles of relevance, completeness, consistency, transparency, and accuracy (WRI et al., 2021).

Inventory boundaries are derived from the geographic area (e.g., administrative sphere of influence or actual city boundary), time period (e.g., one year), the seven Kyoto Protocol GHGs to be covered, and emission sources.

Emission sources are categorized into the six sectors of Stationary Energy, Transportation, Waste, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU), and Other Scope 3 Emissions; additional subsectors are possible.

In addition to the categorization, emissions are divided into three scopes (WRI et al., 2021), See also Figure 1:

- Scope 1 emissions are emissions emitted within the city boundary, allowing aggregation at the regional or national level without double counting.
- Scope 2 emissions result from the use of electricity, heating, water vapor, and cooling within the city boundary, with emissions from generation originating outside the city boundary.
- Scope 3 emissions occur outside the city boundary, but as a result of activities within the city boundary. The inclusion of Scope 3 emissions in the GHG balance is largely optional due to the difficulty of obtaining and preparing data.

Scope 3 emissions are also referred to as upstream emissions, or gray emissions, which occur during the extraction, production, and transportation of energy sources or products and services consumed by city residents (Hoornweg et al., 2011). The decision on the scope of included Scope 3 emissions has an enormous impact on the total amount of emissions accounted for, as this category is mostly the largest item. In one study of eight U.S. cities, the inclusion of the Scope 3 category increased total GHG emissions by

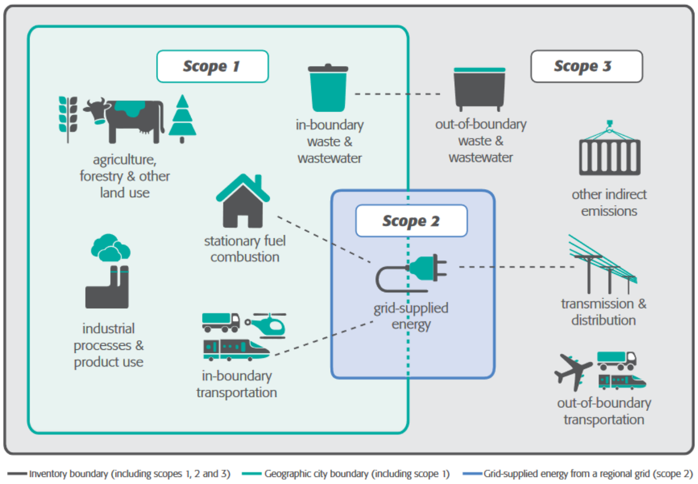

Fig. 1 Relationship between inventory boundaries and scopes in the GPC standard
Source: WRI et al., 2021, p. 36.

47% on average (Hillman & Ramaswami, 2010). In terms of accounting approaches, the scope 1 category clearly corresponds to a pure territorial accounting according to production-based accounting, while the other two Scope 2 and 3 categories follow the consumption-based accounting perspective (Hoornweg et al., 2011).

The GPC standard basically distinguishes between two different but complementary frameworks, the scopes framework and the city-induced framework (WRI et al., 2021). The former intends to report all emissions from activities within the city boundary by categorizing emissions by scopes. The latter allows accounting entities to choose between reporting according to levels known as BASIC and those known as BASIC+. These represent a different scope and level of detail, as each includes only certain Scope 1-3 emissions from selected categories (WRI et al., 2021). Figure 2 shows the sources and scopes covered by the GPC.

3.2.2. Stationary Energy

Scope 1 includes emissions from the combustion of fuels in buildings and industry and fugitive emissions from the extraction, conversion, and transport of fossil primary energy sources. Scope 2 emissions from this sector result from the consumption of energy from the regional or national grid. Scope 3 includes emissions from proportional losses in the transmission and distribution of energy (WRI et al., 2021).

The Stationary Energy sector contains a total of nine subsectors, such as residential, commercial/public buildings, parts of manufacturing, parts of the energy industry, parts of agriculture/forestry/fisheries, fugitive emissions from the processing of coal, and those from the processing of oil and natural gas (WRI et al., 2021). There is an additional residual category for unspecified emission sources. Emissions from energy production in the city, which is fed into the grid from there, represent a special case. These emissions are only taken into account when forming a sum of all Scope 1 emissions. However, they are neglected when determining scope 2 emissions in order to avoid double counting (WRI et al., 2021).

For the building subsectors, there is guidance on dealing with mixed-use buildings (WRI et al., 2021). Manufacturing industries include emissions from the combustion of energy sources in stationary facilities or off-road transportation within the industrial site. If possible, they can be further subcategorized by industry. For this subsector in particular, the standard provides several examples to distinguish it from other sectors (WRI et. al., 2021). In the energy industry, three activities are distinguished: the production of primary energy sources, their subsequent processing and transformation, and ultimately the production of energy that is fed into the grid. Separate discussion is given here to cogeneration, trigeneration, energy production from waste, and bioenergy (WRI et al., 2021). In the agricultural sector, for example, emissions are generated during the use of agricultural machinery and generators (WRI et al., 2021). Fugitive emissions occur during the extraction, conversion, and transportation of fossil fuels. These processes are broken down separately for coal and for oil and natural gas (WRI et al., 2021).

Sectors and sub-sectors	Scope 1	Scope 2	Scope 3
STATIONARY ENERGY			
Residential buildings	✓	✓	✓
Commercial and institutional buildings and facilities	✓	✓	✓
Manufacturing industries and construction	✓	✓	✓
Energy industries	✓	✓	✓
Energy generation supplied to the grid	✓		
Agriculture, forestry, and fishing activities	✓	✓	✓
Non-specified sources	✓	✓	✓
Fugitive emissions from mining, processing, storage, and transportation of coal	✓		
Fugitive emissions from oil and natural gas systems	✓		
TRANSPORTATION			
On-road	✓	✓	✓
Railways	✓	✓	✓
Waterborne navigation	✓	✓	✓
Aviation	✓	✓	✓
Off-road	✓	✓	
WASTE			
Disposal of solid waste generated in the city	✓		✓
Disposal of solid waste generated outside the city	✓		
Biological treatment of waste generated in the city	✓		✓
Biological treatment of waste generated outside the city	✓		
Incineration and open burning of waste generated in the city	✓		✓
Incineration and open burning of waste generated outside the city	✓		
Wastewater generated in the city	✓		✓
Wastewater generated outside the city	✓		
INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)			
Industrial processes	✓		
Product use	✓		
AGRICULTURE, FORESTRY AND OTHER LAND USE (AFOLU)			
Livestock	✓		
Land	✓		
Aggregate sources and non-CO_2 emission sources on land	✓		
OTHER SCOPE 3			
Other Scope 3			

✓ Sources covered by the GPC
● + ● Sources required for BASIC+ reporting
● Sources included in Other Scope 3
● Sources required for BASIC reporting
● Sources required for territorial total but not for BASIC/BASIC+ reporting (*italics*)
● Non-applicable emissions

Fig. 2 Sources and scopes covered by the GPC
Source: WRI et al., 2021, p. 41.

Scope 1 emissions from fuel combustion are obtained by multiplying the emission factor of an energy carrier by its consumption, which represents activity data (WRI et al., 2021). Energy consumption is determined using factors that indicate the average location-specific energy production (location-based method). For activity data of Scope 2 energy use emissions, utilities or surveys can provide actual consumption values. Otherwise, national data modeled or scaled via building types provide relief (WRI et al., 2021). Scope 3 emissions are calculated by multiplying those Scope 2 energy consumptions by a loss factor (WRI et al., 2021).

3.2.3. Transportation

The classification of emission sources in the transport sector is complicated by the fact that traffic often crosses borders. Basically, Scope 1 includes emissions from fuel combustion of all passenger and freight transport within the city boundary. Scope 2 includes emissions from electricity consumption for electric vehicles at intra-city charging stations. Scope 3 includes the shares of emissions from cross-border trips that are outside the city boundary, as well as any emissions from a port or airport. Similar to the Stationary Energy sector, Scope 3 also includes emissions from the proportionate losses in the transmission and distribution of energy that are attributable to electric vehicles (WRI et al., 2021).

The five types of transportation – road, rail, water, air, and off-road – make up the subsectors of the Transportation sector (WRI et al., 2021). For each of the five transport types, very detailed information is provided in the standard.

For the calculation of road transport emissions, for example, there are four methods to choose from (WRI et al., 2021). The first method works top-down and uses total intra-urban fuel sales as a measure of transportation activity (fuel sales method). The other three methods are bottom-up oriented. They are based on the so-called ASIF model (Activity, Mode Share, Intensity, Fuel). According to this model, emissions are calculated by multiplying the mileage by the fuel consumption and the emission factor. For the second method, the number and length of all trips must be known. Then, all intra-urban and 50% of the cross-border trips are accounted for (induced activity method). The third method corresponds to a classical territorial balance and thus includes all transport activities within the city boundary (territorial method). The fourth method includes all transport activities of residents and is therefore comparable to a consumer balance (resident activity method).

Transport activity data can be obtained from surveys, by modeling, by asking the relevant institutions or by scaling regional and national data (WRI et al., 2021).

4. Summary and Outlook for Further Challenges

The paper concludes that at the municipal level, the characteristics of the institution of the municipality as well as the specific purpose of the GHG balance must be in the foreground. This is because a municipal GHG balance mainly forms the control and decision-making basis for the implementation of measures to achieve climate and emission targets. Priority must therefore be given to recording Scope 1 and 2 emissions as correctly and accurately as possible. Only when these necessary prerequisites have been met can and should municipal carbon accounting be expanded to include Scope 3 and consumption-based emissions.

In addition to selecting suitable accounting approaches for a GHG inventory, municipalities face further challenges. It is often not possible to obtain all the necessary data at the municipal level in a sufficiently disaggregated form. The primary goal is always to achieve the highest possible data quality, which increases the fewer estimates and scalings have to be made. To achieve a high proportion of primary data, intensive cooperation with various local institutions and authorities is necessary (DIFU, 2018).

Another key aspect for municipalities is the question of financing. Municipalities have limited financial resources for the accounting of GHG emissions and the subsequent implementation of mitigation measures. This also applies, for example, to the hiring and training of personnel. Although financing is undoubtedly a major challenge, it must be borne in mind that any damage caused by failure to take climate protection measures will be associated with significantly higher costs in the future (Gouldson et al., 2015, p. 5: “Overall, local climate protection measures pay off and lead to considerable savings in the long run”).

The sluggish development of municipal carbon accounting is also due to the lack of binding reduction targets and the lack of obligation. As an aspect of climate protection, carbon accounting fits into the catalog of tasks of a municipality as a voluntary self-governing task (Kern et al., 2005). Related to the challenge of financing, it competes with investments in other voluntary tasks, such as culture and sports. Consequently, in municipalities, a limited additional benefit faces potentially enormous additional costs, creating an incentive problem for carbon accounting (Cochran, 2015). Consequently, the fact that climate protection, carbon accounting and the widespread diffusion of climate-neutral alternatives are associated with economic benefits and other additional benefits, such as improved air quality, ecosystem protection or noise abatement, which increase the quality of life for the municipality's citizens, is all the more important.

In order to work towards a targeted reduction of emissions, the carbon accounting system should be integrated into a holistic carbon management cycle. After the analysis of the actual state, which in this case is done by the municipal carbon accounting and the resulting GHG balance, the five classic stages of the management cycle follow: goal setting, planning, decision, realization and control (Lorson & Haustein, 2022). To increase transparency regarding GHG emissions and achieved reduction targets, the GHG balance can be embedded in voluntary sustainability reporting. In this way, a municipality's sustainability efforts could be presented in a bundled way and accounted for - as well as for the financial use of resources. In addition, sustainability should be further integrated into governance systems, such as internal control and risk management systems or internal audit.

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RAČUNOVODSTVENO OBUHVATANJE EMISIJA UGLJEN DIOKSIDA U JAVNOM SEKTORU – IZAZOVI, PRISTUPI I PERSPEKTIVE NA NIVOU GRADA/OPŠTINE

U današnje vreme borba protiv klimatskih promena i njenih efekata zbog antropogenog efekta staklene bašte jedan je od centralnih izazova za društvo i politiku u cilju sprečavanja daljeg povećanja emisija ugljen dioksida u atmosferi i ostvarenja klimatske neutralnosti. Neizostavni preduslov za izbor, implementaciju i praćenje efikasnosti mera za smanjenje emisije gasova sa efektom staklene bašte je merenje i obračun emisija kroz implementaciju računovodstvenog sistema obuhvatanja tih emisija. U poređenju sa preduzećima, tema računovodstvenog obuhvatanja emisija ugljen dioksida na nivou jednog grada ili opštine do sada je privukla manju pažnju javnosti. Stoga se ovaj rad bavi specifičnim izazovima, pristupima i perspektivama računovodstvenog obuhvatanja emisija ugljen dioksida na nivou jedne opštine.

Ključne reči: *računovodstveno obuhvatanje emisija ugljen dioksida, emisije gasova sa efektom staklene baste, grad/opština, klimatske promene*