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On net zero GHG emission targets for climate protection in cities: More questions than answers?

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Abstract. Two separate, but interacting, global agendas are now leading to new, additional requirements for the future development of cities: The UN Agenda 2030, putting cities at the heart of sustainable urban development with its Sustainable Development Goal (SDG) 11, and the Paris Agreement COP21 adopting the 1.5 °C target as a basis for global emissions reductions. Regulators and researchers have widely recognized the necessity to put cities, as an important object of assessment, and city authorities, as an important actor group, at the core of climate mitigation efforts. For cities themselves this topic becomes a factor of competition among peers. In their pursuit of a low carbon future, however, they are confronted with a number of theoretical and practical questions regarding target setting and subsequent planning for mitigation. As a contribution to the current discussion, the paper initially clarifies on which principles the allocation and accounting of city-related greenhouse gas (GHG) emissions are typically based. A good understanding of the GHG sources and reduction potentials is essential for defining feasible targets and designing efficacious reduction strategies. Built on this, the paper then presents how climate targets are defined at city level and analyses the methodological considerations that arise in the case of target-setting approaches involving bringing the emissions balance to zero. Although first definitions of "net zero emission" concepts on an urban scale can be found in literature, their precise meaning and applicability still remain vague, with unclear system boundaries, calculation and assessment rules. This paper provides a definition framework for clarifying such concepts.

1. Introduction

2015 marks a historic turning point for the future development of cities: The UN Agenda 2030 with its Sustainable Development Goals (SDGs) and the Paris Agreement have put in place new framework conditions for a sustainable transition to a greenhouse gas (GHG) neutral and climate-resilient future. The two agendas cannot be achieved if tackled individually. Climate protection is an important partial aspect of sustainable development and contributes to the preservation of the natural basis for life. Conversely, long-term climate goals can and must only be achieved by sustainable means, and thus, if placed in the wider context of sustainable development. SDGs make this abundantly clear with SDG 7 "Affordable and clean energy", SDG 12 "Responsible consumption and production" and SDG 13 "Climate Action". At the same time, SDG 11 aiming to "make cities and human settlements inclusive, safe, resilient and sustainable" recognises cities as an important level of action encompassing active climate protection as a sub-goal among others.

In this sense, putting cities at the core of climate mitigation efforts is a practical imperative to achieving several SDGs. But it is also a strategic one: although cities occupy only a tiny proportion of the total global surface area (around 3%), over 70% of global CO2 emissions from final energy use can

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be attributed to them [1] (accounting for where emissions are caused, the respective proportion would be about 30% lower). In the absence of action, this proportion will be further raised due to the projected rise of the global population in cities to 2.5 billion plus by 2050 [2]. Today, the potential for cities to limit the magnitude of climate change through effective mitigation actions to reduce their environmental impact is widely recognized [3]. This has led to a continuously growing number of international initiatives and organisations which assist city governments in proceeding towards decarbonisation [4]. This assistance takes a variety of forms, such as international guidelines or reporting platforms (e.g. the carbonn® Climate Registry), broad catalogue of measures (e.g. C40 Cities Climate Leadership Group), or collective agreements (e.g. the Global Covenant of Mayors for Energy and Climate).

However, tapping the full potential of cities in the area of climate protection necessitates the discussion of some basic challenges: first of all, the “city” as an object of assessment and level to act is difficult to define and model due to its dynamic, complex and constantly evolving character. Cities involve not only tangible assets (e.g. buildings and infrastructures), but also intangible values (e.g. cultural heritage, social relationships, etc.) often being important determinants of, or barriers to, progress. In this regard, experts ask for more interdisciplinary collaboration between hard and soft disciplines [5]. The “city” is also a network of actors and agents of change – with the city government as the main one. Secondly, the local climate action plans that are developed and implemented need to be built on long-term ambitious targets, aligned with the global goals. Setting net zero emission targets facilitates city officials to work towards ambitious strategies that are consistent with the required greenhouse gas neutrality by the second half of the century. Nevertheless, the precise meaning and applicability of concepts related to zero emissions remain unclear. The heterogeneity of the different accounting schemes [4, 6] creates problems for target setting, action planning and monitoring of success.

The paper deals with the aforementioned challenges by answering the following questions: a) What is the definition of “city” and its role in reducing GHG emissions as part of a sustainable urban development? b) How the target of net zero GHG emissions increasingly adopted by cities can be more precisely defined? To answer these questions, the city authority’s level of influence and control in each sector and field is taken into account as a necessary ingredient for making change happen.

2. City: “actor”, “level of action” and/or “object of assessment”

A clear definition and system boundary setting of “city” is essential for identifying the different sources of greenhouse gas emissions tied to it. There is no universally applicable definition of what constitutes a “city” yet [7,8]. City is a system of interdependent subsystems that can take on a variety of forms and functions. Depending on the research discipline (i.e. urbanism, geography, economy, sociology, etc.), a city can be seen as an administrative unit, an assemblage of buildings and infrastructures, a system with energy- and mass flows, a place to live and work, a place of history and cultural heritage, a value-creating system, or a network of actors amongst others. All these definitions represent different perspectives with regard to city and exist equally side by side.

It is important to select appropriate urban-specific system boundaries based on the specific targets and research questions [9]. In the context of the present paper, where the aim is to analyse the establishment of aspiring targets for GHG-emission reductions, three of the possible perspectives are considered: (1) the city as a “system” with energy and mass flows entering and leaving its boundary (and therefore a system associated with emissions embodied in the inputs and output of its processes); (2) the city as a “place to live and work” with a corresponding demand for goods and services (demand side) that can be assigned to individual needs (e.g. housing, food and mobility), as well as with a corresponding supply of goods and services (supply side) both in and outside its boundary (i.e. a “place” associated with emissions generated from the production and transportation of products and services to satisfy the “consumers” in the city and emissions directly caused from producers in the city); (3) the city as a “network of actors” whose actions influence directly and indirectly the level of emissions.

The perspectives (1) and (2) have an influence on the way emissions sources are determined and the system boundaries are demarcated. It is not “cities” themselves that cause GHGs [7] but rather particular production and consumption activities by households, businesses, industry and institutions. GHGs are therefore allocated to cities on the basis of either a) being produced within city geographical boundaries (production-based approach (PBA) – accounting at source point) or b) being generated as a result of city actors' use or consumption of goods and services and waste generation (consumption-based approach (CBA) – accounting at end user point) [10, 11]. These two different views of how city GHGs may be accounted for are linked to the capacity and responsibility of different groups of actors (city authority, consumers) to act on limiting the sources and activities that cause the greatest impact [12]. In case a), responsibility is assigned to the producers of emissions, and therefore the actors in charge of the actual sites of the emitting processes (e.g. production facilities). In case b), responsibility is assigned to the final consumers of goods and services irrespective of where they are produced (emissions are associated with their manufacture and transport), and therefore to the actors representing the demand side.

Typically, the choice is made between an accounting procedure as per a) or b) on a macroeconomic level, with the first one being much more developed and widely adopted than the latter one [13, 14]. An exact description of the selected approach is necessary for ensuring comparability when the aim is the assessment or benchmarking of performances and practices – here double counting has to be avoided (a possible risk as illustrated in Figure 1). This was also the intention of the GPC reporting standard which outlines three scopes for the inventorying of GHG emissions [15]: Scope 1 covers the direct emissions from sources located within the city boundary, and therefore the territory-based emissions; Scope 2 includes the indirect emissions that occur as a result of the use of grid-supplied electricity, heat, steam, and/or cooling within the city boundary; Scope 3 includes all other indirect consumption-based emissions.

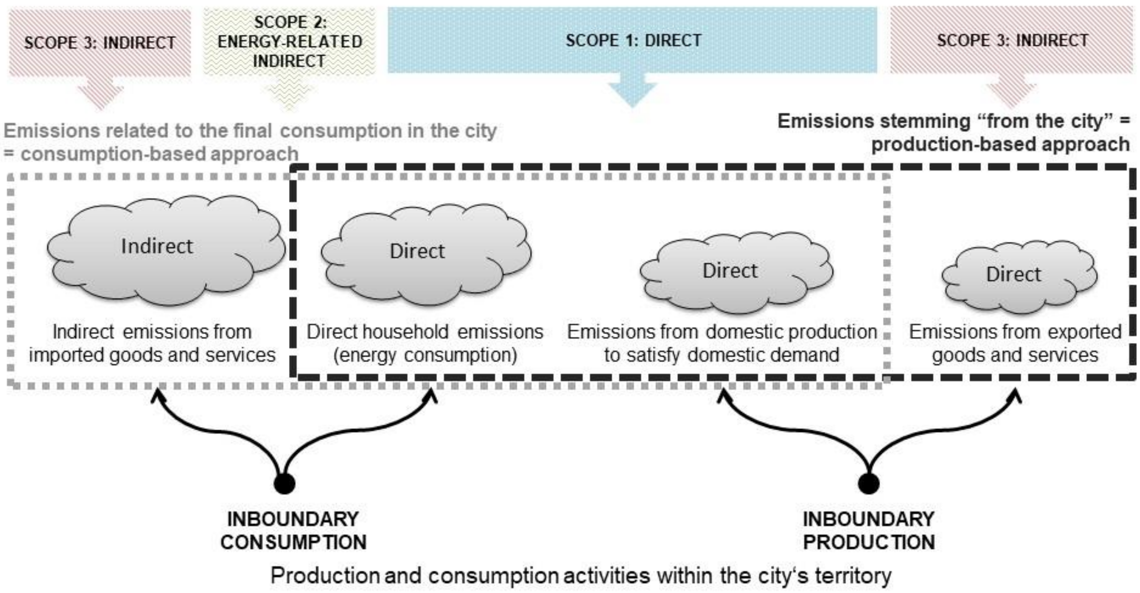

Figure 1. Illustration of the overlapping boundaries between PBA and CBA (adapted from [17]), and their correspondence with the GPC's three-scope framework [15].

For the development of mitigation strategies, the situation is different; the avoidance of double-counting is not a relevant consideration. Perspective (3) leads to the realization that actor-specific strategies are indispensable. Cities should be primarily concerned with the exploitation of all possibilities for action both on the production and demand side rather than the benchmarking of their performances. A narrow focus on PBAs – especially in the case of developed countries (and their cities) as primarily net importers of GHG emissions due to their high-consumption urban lifestyles – leads to substantial proportions of cities' GHG emissions being absent from their local emissions inventories and reduction targets [14]. This proportion can be twice or thrice as high as a city's direct emissions [16]. It is now widely

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recognized that effective policy-making needs to consider both approaches in a complementary fashion [12]. Only by looking at both sides efficiency, sufficiency and consistency strategies can be combined.

Once the system boundaries of the city are defined and sources and/or causes of emissions identified, the latter need to be attributed to, and therefore structured according to, key sectors (and subsectors) – when the supply side is investigated – or consumer needs (e.g. food, housing, commuting, etc.) – when the focus is on the demand side. This allows for an effective and comprehensive accounting of its GHG emissions. Already here the first difficulties arise. So far there is no uniform and generally accepted typology of sources or "polluters". General structuring possibilities for both approaches should be worked out in standardization and harmonization efforts. However, for sector-based structures, GPC [15] can now be considered as a form of "international protocol", since it is the one recommended by the Global Covenant of Mayors for Climate and Energy which counts more than 8000 members. For the consumer-based structures there is no "international" standard for cities, only national ones, e.g. [29].

3. The issue of target setting

The most important concept around which cities share somewhat different views and terms is the GHG (or carbon/CO2) emissions reduction target [18] as a contribution to global climate protection. Both relative and absolute targets can be used in order to assess urban-related GHG emissions and drive the design of policies and measures. Relative means to achieve a certain percentage reduction in emissions against a defined baseline, also known as "base-year target" [19], while absolute means to achieve a certain amount of GHG emissions by a target year (no need to specify a reference/baseline year in this case), also known as "fixed-level target" [19].

A global analysis by the German Federal organizations BBSR and BBR [4], which looked at 21 cities from different regions around the world, showed that many of them intent to achieve relative but not absolute reduction goals by 2030 or 2050. Some cities, however, are already shifting from relative targets to absolute global targets to guide their efforts. This category also involves conceptual targets, such as "carbon neutrality", "climate neutrality", "fossil-free", "energy independence", or "100% renewable". Figure 2 provides an overview of some actual examples of cities with this form of target-setting. This movement towards such targets is also reflected in the emergence of a global network of cities (among other city networks operating at different scales and targeting GHG reductions in cities), the Carbon Neutral Cities Alliance (CNCA), coalesced around a shared commitment to carbon neutrality. The majority of the cities shown in Figure 2 are founding members of CNCA.

Although such absolute long-term targets provide a clear signal to all stakeholders and businesses about the city authority's commitment to a low carbon transition, it is difficult to find clear definitions for these concepts. Focusing on the target of "climate neutrality", according to United Nations [20], being "climate neutral" means (in general terms) to achieve net zero emissions of GHG by reducing such emissions as much as possible, while developing trade-off mechanisms to offset the remaining unavoidable emissions. Climate neutrality can therefore be used as a synonym for the scientific term "net zero GHG emissions" [21]: any remaining ton of CO_2 and non-CO_2 emissions (expressed in units of CO_2 equivalence) is balanced by the so-called negative emissions of CO_2 (i.e. CO_2 removals from biomass regrowth and/or CO_2 capture and permanent geological storage) or through offset credits.

However, although climate neutrality, as defined above, is "the goal to which all urban areas should aspire" (again according to the United Nations [20]), allowing the "balancing out" of the continued combustion of fossil fuels, without specifying minimally acceptable conditions or limits for it makes it less aspiring as "100 percent renewable". Recognizing the dangers of leaving an unspecified room for offsets, efforts are lately focused on a more science-based perspective on the concept of climate neutrality. The negative effects of climate change can be limited if global warming remains below 1.5 °C. This possibly results in a budget of CO_2 or GHG per city or per capita. This is an ongoing discussion and the first contributions can be found at [22].

A budget-like approach has been embraced already by some cities in Germany (and Germany as a whole striving for 1 tonne CO_2 per capita and year by 2050 [23]). For example, the policy document of the City of Berlin [24] considers the ceiling per-capita budget of GHG emissions for the projected population of earth in 2050 (i.e. 9 billion people) that would keep global warming below the threshold of 2°C [25]. According to this, every person on Earth is endowed with 2 metric tonnes of CO_2eq. (life cycle-based), which means that Berlin's target should be to reduce its CO_2 emissions by 85% compared to 1990 levels (Figure 2). Another example is Munich, which, also starting from a science-based approach, sets a seemingly more ambitious neutrality target for 2050, that of 0.3 tonnes CO_2eq. per capita and year, in an effort to align as much as feasible (given the level of political enforceability) with the threshold of 1.5°C (with 66% probability) [26].

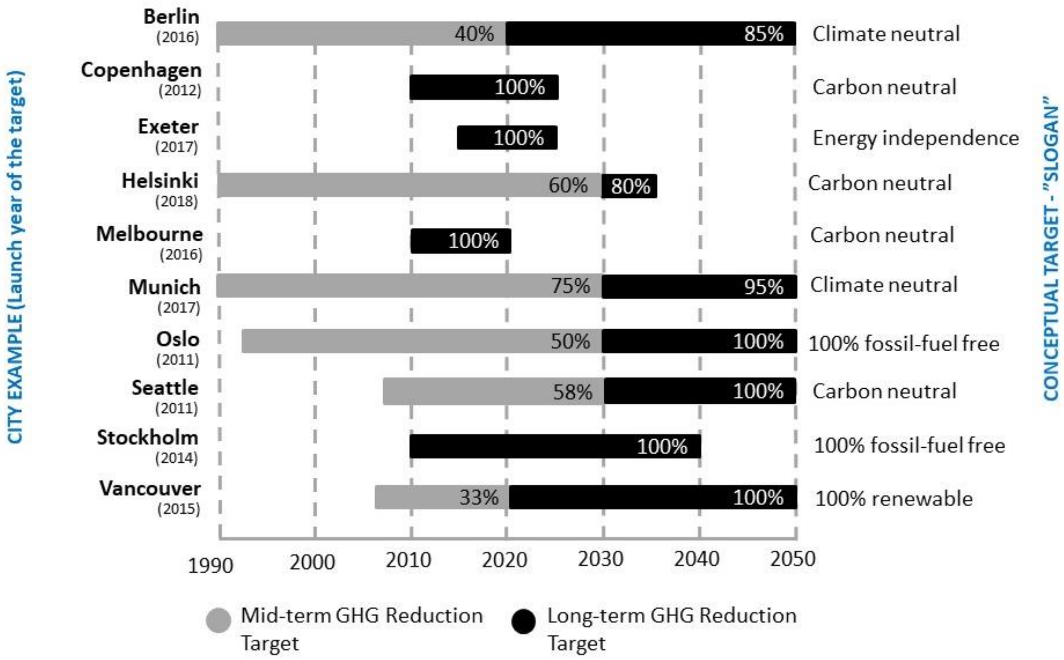

Figure 2. Examples of cities' conceptual long-term targets (adapted from [18] with new additions: Exeter, Munich and Helsinki).

At the same time, the usage of the word "climate" might be misinterpreted; it might be easily assumed that it also refers to air pollutants other than GHGs. Some have thus started replacing it with the term "GHG neutrality" [23]. Additionally, it is often used interchangeably with the term carbon neutrality; however, the last one is unclear as to whether "carbon" refers exclusively to carbon dioxide or other greenhouses gases as well.

Despite the existence of some definitions in literature, "net zero emission" or "neutrality" concepts still remain vague, with unclear system boundaries, as well as calculation and assessment rules; Variations in ways of thinking about these concepts can influence urban development. In this regard, operationalization is required, if they are to be adopted as a goal for the future development of cities [27]. The clarification points presented in Figure 3 are based on the present authors' observations and ideas and can be used as a first step towards improving transparency.

3.1. Type and scope of emissions

Type of emissions: Many neutrality targets merely relate to CO_2 and neglect other non-CO_2 gases [4]. The reason for this can often be attributed to the lack of reliable information on these GHGs. However, these cause up to 40 percent of global GHG effect and should therefore not be omitted from inventarisation, target-setting and mitigation strategies [4]. Indeed, most of existing GHG accounting and reporting standards cover the GHG gases specified by the Kyoto Protocol [15]. However, some cities adopt a middle-road approach, accounting only for carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4) [13].

Scope of emissions: Cities typically estimate Scope 1 and Scope 2 emissions. However, some cities have begun to experiment with consumption-based inventories that extend into Scope 3, e.g. City of Seattle. Although Seattle does not include these emissions in its carbon neutral scenario analysis, it has included a consumption-based inventory in its plan, as well as related actions [28]. This is a good example of a double strategy for exploiting all possibilities for action. Hence the inclusion of a complementary target-setting package according to the "consumer-based" approach is recommended by the authors to obtain a real picture of energy consumption and GHG emission balance. This is also useful for bringing citizens and local stakeholders "on board" as end-users and encouraging them to assume responsibility, since in many cases the share of emissions caused directly by municipality is rather small. It is no coincidence that C40 Cities recently released a new study establishing consumption-based GHG inventories for its 79 member cities on the basis of PAS 2070 methodology [29] with the aim "to better understand the ability of cities to contribute to GHG emissions reduction activities beyond their city boundaries" [30]. This study specifically reveals that cities have a 60% increase on their carbon footprint, compared to the previous estimations for the same cities using the GPC's sector-based approach [30]. Without doubt, this undertaking implies that the time is ripe for utilizing additional accounting approaches in city-level target-setting as well as that the window of opportunity to influence consumption patterns is huge.

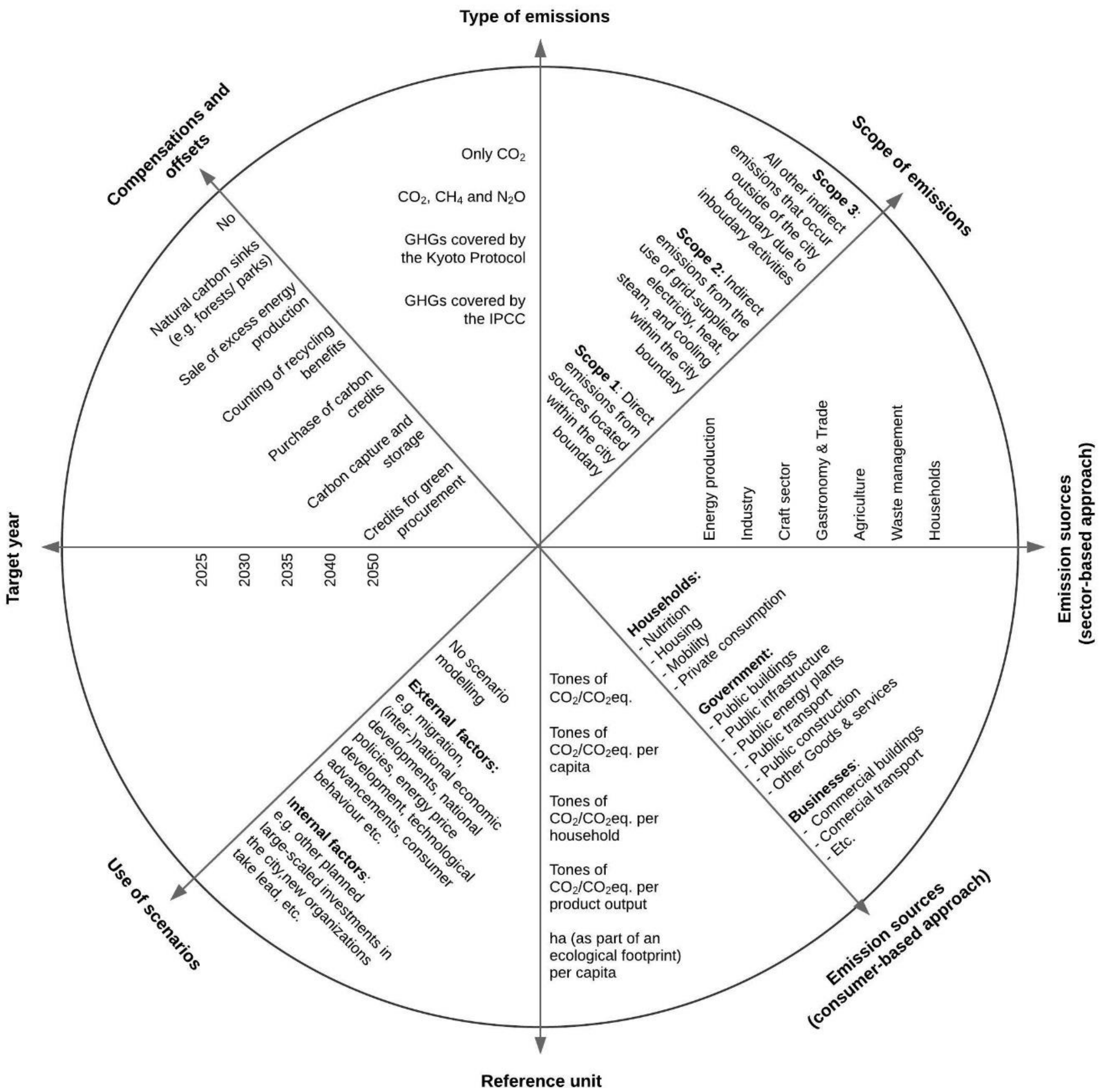

Figure 3. Aspects that need to be clarified for net zero emission and similar targets on city level.

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3.2. Emissions sources

Emission targets can be set either for the entire suite of emission sources (activities in a city) represented and accounted in the GHG inventory or only for the ones over which the city governments have the greatest direct influence. While setting goals over all (or nearly all) emissions makes sense at national level (e.g. as part of the Intended Nationally Determined Contributions (INDCs) submitted under the Paris Agreement), this may be counter-productive for city-scale GHG inventories [31]. For example, some cities are dominated by emissions from large point sources, such as power plants and industrial facilities (usually serving demands far beyond the city boundary), over which they have little influence. It is recommended that cities initially exclude such emissions (only from the balance, not from the list of necessary actions – influencing industry is also essential for reducing impacts to local environment, in addition to GHGs) and instead follow a step-by-step approach, starting from the target of establishing a “GHG neutral” city administration. In addition to the decision of which sources to include in an inventory, the breakdown itself can also have an influence on the results. Figure 3 presents a breakdown both for sector-based and consumer-based approaches. The first breakdown follows the structure of macroeconomic sectors. The logic behind the second breakdown is to clearly distinguish between the different types of consumers (households, government and businesses) and the most common fields of need assigned to households, as well as end-uses assigned to other consumers, according to the currently available end-use classification frameworks. The latter is also largely compatible with [29].

3.3. Reference unit

The emission quantities can be expressed using different units and/or methods of normalization (e.g. per capita, per gross city product, etc.). For example, setting targets for per-capita emissions, in addition to overall emissions, ensures that expected population growth is being accounted for. In general, the indicator GHG emissions per capita and year is becoming central in the global debate and has already been adopted several cities as earlier described.

3.4. Temporal aspects

Use of scenarios: When planning is built in a long-term goal, understanding the baseline emissions scenario(s), also referred to as business-as-usual (BAU) emissions scenarios, is essential for better dealing with the uncertainties of the future. BAU represents the future emissions with the highest probability of occurrence in the absence of a mitigation target. Developing a baseline scenario typically requires a wide variety of inputs, such as data on critical GHG emission drivers, assumptions about how these drivers are expected to change, and information on policies that may cause these changes. On the other hand, a target scenario represents the cities’ future GHG emissions based on the likely reduced emission levels caused by the planned actions (depending on whether action planning precedes or follows target-setting), and thus it shows the reduction pathway. The “distance” between a city’s BAU and target scenario equals the emissions savings. There are many methods of scenario modelling that can be used [32] and various cities have extensive experience in using them, but this is not part of this paper. It is important though to distinguish “external” factors – i.e. factors capturing the uncertainties emerging from the outside world and not in the sphere of influence of the city authority, such demographic, economic and technological developments – from “internal” factors – i.e. factors that include future developments shaped by the decisions of city authority [33]. The development of scenarios as a process can also be used for another purpose: to support and stimulate larger scale discussions with non-experts and enlarge the circle of decision-making through workshops [27, 33].

Target year: Another question is how to decide upon the horizon over which the end target needs to take place. The time frame chosen influences the need for including interim targets. Setting intermittent targets as near-future milestones to compliment the longer time frames necessary for achieving overarching targets could bring several benefits [34]. This increases the particularity and practicality of the climate plan, as well as the sense of urgency, responsibility and political commitment, leading to the enhancement of the overall credibility of the “reduction path”. Indeed, Figure 2 shows that most of the cities with targets beyond 2025 have also interim targets in place.

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3.5. Compensations and Offsets

Several cities have adopted compensation and offsetting measures as an option for fulfilling their total carbon reduction targets. It is important to place restrictions on offsetting the unavoidable emissions in order to ensure that the focus is not shifted from overall emission reductions. This means that before anything else cities have to work on their own mitigation strategies, so as to reach the optimum level of emission reductions that can be achieved, and then take the offset possibilities as a way to balance the remaining emissions. Additionally, detailed guidance is required around the types of offset allowed, for example, in terms of whether offset actions occur onsite (e.g. production of a surplus of green energy, as in the case of Copenhagen planned to offset part of its CO_2 emissions through the provision of excess wind power to the electricity grid [35]) or offset credits are purchased from a third party (e.g. Melbourne included the purchase of carbon offsets in its 2020 plan [36]), and in the latter case, how credible the offset provider is [37]. Figure 3 shows different options for addressing a city's remaining emissions. The pros and cons of each option are explored in [28].

4. Conclusions and Recommendations

Despite the lack of a shared understanding of net zero concepts, several cities and developments around the world claim to be on the path to net zero GHG emissions, mostly focusing on a combination of efficiency and consistency strategies (improvement of energy efficiency and increased use of renewable energies). If the demand side is included, the addition of sufficiency strategies is indispensable. However, even under the condition that common understanding will be reached in the future, comparing the climate efforts of different cities around the world in terms of their "distance" to net zero emissions target would not be reasonable. It is an indisputable fact, that the starting position of each city with respect to mitigation and the way in which each one of them intends to achieve its claimed status often differ considerably [27]. The issues earlier described are not the only ones requiring attention. They bring out the need for further work in other related areas. The present authors identify implications and consequences in the following fields:

Data collection: Strong and comprehensive data that enable the tracking of changes over time is a prerequisite for any systematic work on monitoring, assessing and reducing GHG emissions. Most cities lack sources of such data. Especially in the context of the deregulation of energy markets, there is hardly any institution/body collecting all the energy consumption-related data. An additional problem is that this type of data is usually subject to data protection laws. This forces the city authorities and the experts commissioned by them to be dependent on the analysis of (partial) data from different sources. Under these conditions, besides their necessary involvement in the development and implementation phase of the action plan, industries and citizens should be also actively involved in the provision of the necessary data to ensure a more comprehensive accounting and assessment.

Reporting instruments: Cities can benefit from borrowing ideas and practices from big companies; one example is the instrument of sustainability reporting that can also be used by city authorities for the formulation of goals and the monitoring of the compliance with them.

Standardization: Currently, it is unlikely that there will be an international agreement on harmonized methods and procedures for the net zero GHG emissions approach in cities in the form of one international standard. It is rather likely that an even greater number of approaches will continue to be pursued in parallel. It is, however, important to first attempt to reach a more global consensus on a set of minimum information (including the system boundaries, the offsetting methods and limitations, etc.) to be reported in the future when municipal climate protection concepts are published. In the medium term, the development of a standard leaving adequate leeway for adaptation to the local situation, while supporting a transparent declaration of used methods and system boundaries and providing a basic typology of cities is possible. The profiles indicators according to ISO 37120 [38] already provide a good basis for the latter; the definition of cities' profiles for the purpose of fairer cross-city comparisons.

In this sense, this topic cannot yet be considered as completed and further investigation and discussion is needed.

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