On the definition and prioritization of strategies and actions to minimize greenhouse gas emissions in cities: An actor-oriented approach

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M Balouktsi[1], T Lützkendorf[1]

[1] Centre for Real Estate, Karlsruhe Institute of Technology, Karlsruhe, Germany

Email: maria.balouktsi@kit.edu

Abstract. Cities as hotspots of human economic activity and infrastructures provide some of the best opportunities for decarbonizing sectors essential for limiting the global warming to 1.5, such as buildings and transport. For this reason, 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. In their pursuit of a low-emission future, however, cities are confronted with a number of theoretical and practical questions regarding allocation and accounting of city-related greenhouse gas (GHG), target setting and subsequent planning for mitigation. A wide literature is currently focused on the first two. However, to achieve ambitious climate targets, research should urgently focus more on how to reap all available urban mitigation actions and encourage rapid and radical changes. Identifying and prioritising mitigation strategies and actions to achieve the targets, as well as putting them together into a coherent plan with a clear vision of the future, are critical steps in actionable and effective climate action planning. As a first contribution in this direction, this paper provides recommendations for research and practice to support a more integrated and conscious definition and prioritization of actions by municipal stakeholders, based on: (1) the specific context of each city type as a determinant of what actions may work, (2) the executive power of city authority to act as the main actor and (3) the multiple benefits and/or trade-offs accruing from each local climate action.

1. Introduction

It has now become common knowledge that the collective commitment of nations to the COP21 target to keep global warming to well below 2 (or 1.5) degrees Celsius compared to preindustrial levels is predestined to fail if climate action is limited to national or regional levels [1]. Cities as dense hotspots of human economic activity are key originators of climate change; although they occupy only a tiny percentage of the world's landmass, cities' residents consume over two-thirds of the global energy consumption and up to 70 percent of GHG emissions [2]. In this context, the vast opportunities the cities provide for decarbonizing sectors essential for tackling global warming, such as buildings and transportation have already been widely recognised by both scholars [3] and regulators [4]. This has led to an increasing number of local governments committing to climate and energy pledges and developing local climate action plans (CAPs). Often, these commitments and activities take place within the framework of cities' participation to different transnational city networks. Prominent examples of such networks are the EU Covenant of Mayors (EU CoM) and the Compact of Mayors (CoM), which were recently merged together to form the largest global coalition of cities and local governments, the Global

Covenant for Mayors for Climate and Energy (GCoM) [5]. According to the recorded data provided by the GCoM online platform, about 60 percent of its more than 9.000 signatories already have some sort of local CAP in place. This percentage is almost exclusively made up of European cities. Indeed, in France, Slovakia and the UK, the adoption of local CAPs is even compulsory for municipalities [6].

Although these numbers are in overall promising, not any type of climate plan is sufficient. In addition to the necessity for cities to increase their ambition and strive to limit their emissions as close to zero as possible by 2050 – an urgency signified by the recently released Special Report on Global Warming of 1.5°C (SR15) by IPCC which confirms that current national government commitments are still far from 1.5°C compatible action [7] – cities should accomplish this in the most sustainable way possible. Climate action is not an issue to be considered in isolation; it is one of the sustainable development goals (SDGs) of UN Agenda 2030 (i.e. SDG13) and is significantly linked – positively or negatively – with achieving many of the other SDGs [8].

However, the delivery of a low-emission, sustainable future by city authorities presupposes the confrontation with a number of theoretical and practical questions regarding: (1) allocation and accounting of city-related greenhouse gas (GHG); (2) target-setting; (3) planning for mitigation actions without compromising on other sustainability priorities. The present paper is focused on the latter. To achieve ambitious climate targets, research should urgently focus more on how to reap all available urban mitigation actions and encourage rapid and radical changes. Identifying and prioritising mitigation strategies and actions to achieve the targets, as well as putting them together into a coherent plan with a clear vision of the future, are critical steps in actionable and effective climate action planning. However, doing so is not as easy as it seems. First, as different city types are confronted with different challenges, no "one size fits all" measures exist. Second, city authority is directly responsible for only a small proportion of the city-wide emissions, making the cooperation with non-state actors necessary. Third, conflicting and incommensurable aspects such as environmental, economic, social and technical issues, as well as conflicting stakeholder interests should be addressed simultaneously.

It is no surprise that a recent survey by the EU CoM Office assessing the capacity needs and knowledge gaps for the design and implementation of Sustainable Energy and Climate Action Plans (SECAPs) showed that "defining and prioritising actions based on certain criteria" is where EU municipalities need strongest support, after "implementing adaptation options" [9]. This lack of guidance on the identification and prioritisation of mitigation (and adaptation) actions acknowledged among local authorities presented the primary motive for the present paper, which provides recommendations for research and practice to support a more integrated and conscious definition and prioritization of actions by municipal stakeholders. These recommendations are founded on three areas of opportunity identified during the assessment of existing local CAPs and related literature: (1) the possibility to facilitate and accelerate the identification of climate actions that work for each city type; (2) the possibility to mobilise all stakeholder groups, either belonging to the "producers" or "consumers", and integrate them into future municipal concepts for climate protection through actor-specific strategies to exploit the city's full reduction potential; (3) the prospect and importance of integrating co-benefits and co-harms.

2. Identifying climate actions that work: City typology as a basis for peer-to-peer learning

Nowadays, there is great variety of generic listings and categorisations of climate actions (e.g. see [10, 11, 12, 13]) that can form a basis for cities in the definition of potential actions to include in a CAP. Examples of climate actions grouped under general action categories are also provided by the EU CoM [14]. In addition to these typical lists, cities can also learn from implementation experiences in other cities. Knowledge and expertise-sharing, as well as learning from already realized good practice initiatives, is often one of the main reasons that cities take part in national and transnational city networks. Access to good practices is provided by these networks in several forms; for example, EU CoM promotes the transfer of good practice through the provision of a related database [15], while C40 and Carbon Neutral Cities Alliance (CNCA), as organisations promoting bold city commitments, have

created brochures containing information about particularly innovative local climate projects that go beyond conventional good practice (i.e. Cities100 report [16] or the CNCA game changers report [17]).

However, cities vary in many ways, including geography, climate, size, economy, governance and level of provision of different infrastructures. As different city types are confronted with different challenges, no "one size fits all" measures exist when it comes to climate mitigation. Cities need to focus on different sectors, strategies and actions according to their geographic, socio-economic, and political context. An action proved to be effective in one city may not be in another. Therefore, a way to increase the chances of successfully propagating the application of good practice and innovative climate solutions among cities is to follow a tailor-made approach to policy advice. City typologies are powerful and practical tools for comparing and obtaining knowledge on cities while maintain contextual dimensions. A typology in principle is a system used to group specific objects based on similarities [18]. Typologies combined with case studies demonstrating good practice and innovative solutions could stimulate peer-to-peer learning on urban climate solutions, on the basis that similar conditions (represented through typologies) probably lead to similar solution and innovation spaces. Furthermore, the application of typologies allows focusing on cases that can be meaningfully compared and a context-oriented generalisation of successful mitigation approaches.

It is no surprise that initiatives compiling city typologies as a basis for appropriate policy- and decision-making (in the context of climate mitigation and sometimes of overall urban sustainability) or more contextualised city comparisons have proliferated over the last years. Attempts to determine attributes that contribute to urban energy and greenhouse-gas emissions, and in some cases grouping cities into different clusters according to these attributes, are found not only in academic literature (e.g. [19], [20]) and reports/platforms of knowledge institutions and organisations (e.g. [21], [22]), but also in practical tools (i.e. the CURB tool – the recommended tool to use by the Compact of Mayors for the development CAPs [12]). Similar attempts are also available in Europe in connection to the overall topic of urban sustainability (e.g. [18], [23]). Table 1 provides a concise insight into a number of common (and less common) determinants of GHG emissions found among these various sources, including the classification levels (if any) either empirically employed or obtained through the application of clustering algorithms to real data sets. Finally, the approach of ISO 37120 [24] to considering city characteristics in the form of a set of background information (called "profile indicators") in an endeavour to help cities determine the most relevant cities for peer comparisons can also be seen as a related development towards urban typologies.

Despite the noteworthy progress made in this field, up to present, there have been no systematic and extensive attempts – to the authors' knowledge – to connect such typologies to urban case studies of climate mitigation and adaptation. A good starting point and example of such an attempt constitutes the online case study docking-station hosted by Urban Climate Change Research Network (UCCRN) [21] which at the moment includes more than 120 city case studies (with only 26 case studies from Europe, mostly focusing on adaptation measures). This database allows cases to be searched and grouped by geographic, climate and socio-economic variables (i.e. the Human development index (HDI) and Gross National Income (GNI)), and it therefore has the potential to enable meaningful comparative analyses. In addition to the customizable search criteria, the case studies are also documented on the basis of a standard format, increasing transparency in the contextual elements surrounding each case study.

On the other hand, although the good practice database of EU CoM contains more than six thousand real examples of measures, it misses the chance to fully support an accessible, in-depth peer learning experience, since: a) the description of the key actions (case studies) is surprisingly short (sometimes even presented in the local language) and without an explanation of what processes led to their success; b) the only context specific factors provided to filter these examples are the population and country. EU CoM should learn from the example of UCCRN and improve the function of its good practice database by allowing the identification of more sophisticated knowledge clusters.

Table 1. Selected determinants of urban GHG emissions with the potential to serve as "background information" for context-differentiated mitigation actions in cities.

Determinant of climate action	Study/Source	Any classification included in the study?	Focus	Ref.
Population size⇗	Zoeteman et al. (2015)	Threshold value for "large city" (> 1 million residents)	Europe	[23]
	EU CoM Database	5 levels: Form "very small" (< 10.000 residents) to "very large" (> 500.000 residents)	Europe	[15]
	KPMG (2010)	3 levels: From "small" (< 1 million residents) to "large" (> 3 million residents)	Europe	[22]
	UCCRN Case Study Docking Station	6 levels: From "very small" (< 100.000 residents) to "mega" (> 10 million residents)	Global	[21]
Population growth⇗	Zoeteman et al. (2015)	Threshold value for: "growth city" (> 7,5% population growth over the last 10 years)	Europe	[23]
Urban density (e.g. persons/km^2) ⇘	Baiocchi et al. (2015)	Threshold value: 5.000 residents/km^2	UK	[19]
	Zoeteman et al. (2015)	Threshold value for "compact city": > 2.500 residents/km^2	Europe	[23]
	KPMG (2010)	3 levels: From "low" (< 2.000 residents/km^2) to "high" (> 4.000 residents/km^2)	Europe	[22]
	Creutzig et al. (2015)	Threshold value: 350 residents/km^2	Global	[20]
Measure of wealth (e.g. income, human development index (HDI), etc.) ⇔	Baiocchi et al. (2015)	Threshold value: 900£/week (average weekly total household income)	UK	[19]
	Zoeteman et al. (2015)	Threshold value for "wealthy city" (> €50,000 GDP in million (PPS))	Europe	[23]
	KPMG (2010)	3 levels: From "low income" (< €21.000 GDP/ capita) to "high income" (> €31.000 GDP/capita)	Europe	[22]
	Creutzig et al. (2015)	Threshold value: $10.000/capita	Global	[20]
	UCCRN	4 levels: From "low income" (< $1.045 GNI/ capita) to "high income" (> $12.736 GNI/capita) 4 levels: From "low HDI" (< 0.55) to "very high HDI" (> 0.8)	Global	[21]
	CURB tool	Used as a filter; No clear classification levels	Global	[12]
Dominant economic sectors (i.e. dominant economic structure)	Zoeteman et al. (2015)	Threshold value for "green city" (> 30% area of forests) Threshold value for "tourist city" (> 6,000 of total nights spent per 1,000 inhabitants by tourists) Threshold value for "harbour city" (>0.3% area of ports)	Europe	[23]
	KPMG (2010)	5 economic sectors: "services", "tourism", "transport", "light industry", "heavy industry"	Europe	[22]
Climate (e.g. heating degree days (HDD)⇗)	Baiocchi et al. (2015)	Threshold value: 2120 $HDD_{15.5}$	UK	[19]
	KPMG (2010)	3 levels for average temperature: "cold" (4-8 °C), "temperate" (9-12 °C); "hot" (> 12 °C)	Europe	[22]
	Creutzig et al. (2015)	Threshold values: 1850 and 3020 $HDD_{15.5}$	Global	[20]
	UCCRN	3 Latitude range types (i.e. equatorial, mid-latitude, sub-tropical)	Global	[21]
	CURB tool	7 Climate types (e.g. continental, desert, dry, highlands, etc.)	Global	[12]
Condition of the housing stock	Baiocchi et al. (2015)	Indicators: (1) poor housing condition; (2) Central heating	UK	[19]
Gasoline price	Creutzig et al. (2015)	Threshold value: 1,2 $/litre	Global	[20]
Urban governance	KPMG (2010)	3 levels of EU's index for voluntary participation of residents in organizations: From "low index" (<0.5) to "high index" (>1)	Europe	[22]

⇗ Positive correlation (i.e. when the variable increases, also the GHG emissions increase)
⇘ Negative correlation
⇔Mixed evidence
Note: Both ISO 37120 [24] and the new typology tool of EEA [18] include more than 40 indicators/classification parameters in the criteria identified in table, but these are not included due to limited space.

To this end, as a first step it is proposed to expand the search filters in EU CoM database and at least include "climate" and "population density" in the mix, as two easily obtainable parameters influencing the impact of the most two critical sectors on city level, i.e. buildings and transportation. The first parameter is an especially strong driver of energy consumption and associated GHG emissions in buildings, since heating and cooling demand may vary widely across cities with different climates, even in the same region. The second parameter negatively correlates with transport emissions, since cities characterized by a sprawled development normally entail a significantly higher reliance on private motorized transport. As a second step, it is proposed to select the most "forward-looking" cases out of all the good practice cases in each city-cluster and present them in an analytical form to assist replicability.

Of course, it is recognised that more in-depth research is needed on methods and opportunities to bring together typology approaches with case study knowledge. Table 1 intends to provide inspiration both for future research in the area of associating city typologies with climate interventions and for further advancement of the already existing case study databases of city networks. In the latter case, depending on whether a case study database has a European or global focus, respective classification levels can be applied as search filters. Some determinants are only relevant when looking at a global level – e.g. the gasoline price does not significantly differ among European countries – as well as the interpretation of low and high values of particular indicators, e.g. income, are region-specific (all (or almost all) European cities are "high income" according to the "world bank" income classification as well as have a Human Development Index above 0.8).

Finally, it should be considered to also include even more than before qualitative classification parameters in cities typologies, especially in relation to governance. Cities' executive power over certain areas of action and political constraints can significantly influence the decision of which action pathway to follow. This topic is further discussed below.

3. Designing mitigation strategies: Actor-oriented concepts as a basis for involving urban stakeholders

The degree of power and control city authorities have over different sectors and climate actions varies. Typically, only in few cases the "city authority" is the most important change agent; the effectiveness of the majority of policies depends on the willingness of groups of actors (institutions and individuals) to change the way they produce goods or their behaviour and lifestyle. This is also reflected in a C40 research report which states that only 18% of the necessary actions to be in place by 2030 in its city signatories are directly related to assets or functions where cities have high power, and can therefore be unilaterally initiated and implemented by cities [25]. Concerning emissions impact, this "high power" translates to 5% of the total city impact (excluding the positive impact of grid decarbonisation) [25]. Indeed, this number is close to the reported GHG emissions for city operations in several local CAPs regardless of location (e.g. city government is only directly responsible for about 4% of Oslo's GHG emissions [17], while in New York City (NYC) direct responsibility accounts for about 6% [26]).

It therefore becomes clear that although city authorities are responsible for the generation of the GHG emission inventories, they are not exclusively responsible for all of the emissions reported; some sources can only be influenced by national governments (e.g. industry and centralised electricity supply), while the influence on other sources heavily depends on getting residents, private businesses and investors to act. In that sense, although the development of a GHG emissions inventory establishes a base to identify hotspots and priority mitigation options based on the emission intensity of each sector and activity, it is not sufficient for an effective climate action planning. It is also important for cities to understand their powers and possibilities to deliver real impact both directly (e.g. in the form of immediate GHG reductions through the energy-efficient renovation of existing public buildings), and indirectly (e.g. triggering private sector investment in green solutions) [27].

From the authors' point of view, when grouping actions under strategies or sectoral targets in CAPs distinguishing between "direct actions" – the actions which are in the direct control of each key active stakeholder (with the main one typically being the local authority) and for which direct GHG emissions

can usually be quantified – and "indirect actions" – the actions that can only be indirectly influenced by each key active stakeholder and for which the actual delivery of tangible GHG savings presupposes the commitment from other parties (and therefore the effects of these actions are difficult to quantify) – is a useful exercise and provides a clear signal to businesses and communities on their individual responsibility to take action. For instance, although the "city authority" typically is an important implementing agency when it comes to the provision of the necessary infrastructure, it does not have such a central role in every single field of action; often, its power is restricted to just motivating and stimulating private actors to act through tambourines (information and training), carrots (financial incentives) or sticks (regulatory actions) [28]. On this basis, Figure 1 provides an overview of such an action typology. Whether regulatory actions are considered "direct" or "indirect" actions depend on the level of their enforcement. In Figure 1, these actions are classified as "direct".

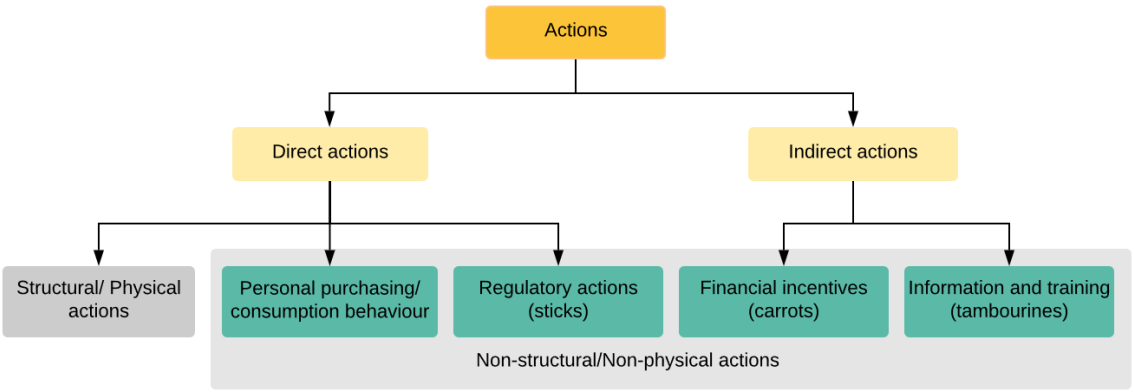

Figure 1. Classification of actions

Of course, each city takes a different approach to structuring its CAP. However, the "level of power" is not as highlighted as expected in the different action planning guides and local CAPs (e.g. see [29]), neither as a criterion in the prioritization of actions nor as a qualitative factor to simply categorize actions. There are good practice examples though that can provide inspiration: (1) In a similar logic as Figure 1, a distinction between "major actions" (i.e. actions with a measurable impact) and "enabling actions" (i.e. indirect actions that enable, accelerate, or multiply the effect of the major actions, e.g. campaigns about climate change and better training for the workforce) is employed by NYC in its recently published CAP [26]; (2) To assist cities in the prioritization of actions, C40 provides a scoring framework broken down into four main power categories – i.e. "Own/operate", "Set/Enforce Policies and Regulation", "Control Budget" and "Set Vision" – each with a score from 0-3, with "3" indicating "strong powers" [25]. This framework is also used in a simplified form by the climate action planning tool CURB [12] to allow users to select which action fields they desire to target based on their city's authority to take action in each field (among others); (3) To help Chinese cities select and prioritize their policies in their CAPs, BEST Cities Tool [11] qualitatively evaluates each policy in terms of the city government capabilities needed in three areas, i.e. Finance, Human Resources, and Policy Enforcement.

All the above are examples of how the topic of "power" can be treated in climate action planning. However, understanding and identifying in which areas city governments have direct power and in which only limited power is not only useful for prioritizing actions. It is also useful for identifying potential collaborations with the private sector. Following the typology proposed by the authors, Table 2 distinguishes between city authorities and private actors based on which kind of influence they typically exercise per subsector/field (direct, indirect or none). From this table, it immediately becomes clear where city authorities should create an attractive environment for business and communities to act and seek potential partners; a city's capacity to take action is not only a matter of power, but also of governance.

Against this background, the roles of private actors in taking action at the community and city level to respond to climate change should not be neglected. A clear assignment of responsibilities/ accountabilities and actions to appropriate agencies, organisations or stakeholders for implementation has been a missing element in many CAPs up to now ("actorless" concepts). Again, as good practice CAP example is the Climate Action Plan of NYC which for each action specifies one or more city agencies or institutional actors that will lead to its implementation [26]. Furthermore, in any case, the development of policies and measures should be accompanied by information provision for affected stakeholders to support implementation and raise awareness. Regardless of what the final structure of the CAP would be, the involvement of private sector and civil society in co-creating and drafting the CAP can result in more effective implementation through increased ownership and acceptance by non-municipal actors. Where traditional approaches become insufficient, the latter can also be strengthened through clearly communicating co-benefits (as discussed in the following).

Table 2. Type of influence typically exercised by city authorities (CA) and private actors (PA) per field and sub-field of action

Sector/ Field of action	**Subsector/Subfield**	**Type of influence exercised by:**	
		City Authorities (CA)	**Private Actors (PA)**
Building stock	Privately-owned buildings	Indirect	Direct
	Public/city-owned* buildings	Direct	None
Urban planning	Land use and spatial planning	Direct	None
	Private urban space planning	Indirect	Direct
	Urban lighting	Direct	None
Transportation	Public passenger transport operated by the city	Direct	Indirect
	Public passenger transport operated by the private sector	Indirect**	Direct
	Private passenger transport	Indirect	Direct
	Freight transport	Indirect	Direct
Energy supply	Privately-owned power and/or heat supply (within the city)	Indirect	Direct
	City-owned power and/or heat supply (within the city)	Direct	Indirect
	Centralised power and/or heat generation (outside the city)	None	None
	Urban lighting	Direct	None
Waste management	City-owned waste management facilities	Direct	Indirect
	Privately-owned waste management facilities	Indirect	Direct
	Waste management facilities operated by regional waste authority	None***	None
Water supply and treatment	Privately-owned community-based water supply	Indirect	Direct
	City-owned water supply	Direct	Indirect
Industrial production and retailers		Indirect	Direct
Consumption patterns	Public Procurement	Direct	None
	Household consumption (food, appliances, etc.)	Indirect	Direct

Notes:

* This category may include commercial buildings/establishments, and office buildings, institutional buildings, such as schools, hospitals and government offices, and city-owned residential buildings.

** Often, the cities procure public transport services from private companies, therefore, the city can have an indirect influence through the criteria set in its procurement procedures

*** An indirect influence may be exercised, but the situation varies from country to country.

4. Going beyond climate impact: The significance of prioritising actions using co-impacts with other sustainability goals

In a review conducted by Balouktsi [29], in which selected literature sources were examined to identify which criteria are typically applied to solve the problem of climate action prioritization, it was observed that the dominant pattern is to prioritise investment in "cost-effective" and "low hanging fruit" (i.e. quick and easy actions, also called "quick wins") actions. Indeed, finding the most cost-effective actions is important especially for municipalities with limited budget. At the same time, with the inclusion of easy to implement short-term actions in a CAP, municipalities can effectively demonstrate the added value produced by the plan and more easily engage people in contributing to the reductions until the longer-term benefits of the plan become apparent [30].

However, for achieving ambitious 2030 and/or 2050 targets cities will need to ensure that they move beyond low cost opportunities with fast returns and also pursue more investment intensive, systemic solutions – such as urban densification and land-use planning – that take longer to yield their full potential but will be critical in achieving the required decarbonisation by mid of the century [31]. The business case for integrating such actions into CAPs can be enhanced by looking at their co-benefits, i.e. the non-climate positive side effects [29]. Beyond addressing climate change, certain climate actions may contribute to the achievement of other local sustainability objectives in areas such as health, safety, housing, air quality, land use, poverty reduction and local economic development.

There are at least two reasons the full range of co-benefits of actions (to the extent possible) should be considered in action prioritisation: First, actions delivering multiple benefits at once – the so-called "win-win" actions – are usually cost-effective. For example, Ürge-Vorsatz et al [32] show that co-benefits of thermal retrofits of residential buildings can add up to as much as 75-350% of direct energy-saving benefits (in the context of a cost-benefit analysis) depending on the geographic location, the deepness of retrofitting and the types of co-benefits taken into account among others. This implies that the total magnitude of positive side effects of an action may exceed its climate benefits, and therefore, their consideration can profoundly change the rank ordering of preferred choices. This has implications in terms of prioritisation between actions and allocation of available funding. Second, the inclusion of co-benefits increases the likelihood of the success of the respective action by engaging more diverse communities of interest (also as investors) and demonstrating compelling added value for them [29, 33]. In other words, co-benefits can serve as a basis for framing the climate action conversation around what private households and businesses care about – i.e. local and near-term positive impacts on energy bills, public health, mobility and employment among others.

Although a growing interest in highlighting co-benefits in local CAPs is noticeable [29], the inclusion of a larger list of sustainability indicators to assess the significance of positive side effects of actions is still not the norm. A recent study by Ruth et al. [34] investigating 36 CAPs both from developed and developing countries provides similar findings; it reveals that while the majority of them (75%) identified co-benefits, very few cities include comprehensive assessments of the magnitude of these positive impacts associated with each action category. However, it should also be pointed out that an action may also be associated with co-harms or trade-offs (i.e. unintended adverse consequences). For example, while increasing urban density may reduce emissions due to transportation [20], without careful design it can also increase flood risks and intensify urban heat island effects (i.e. if densification is realized at cost of green space) [35]. For actions to be "low-regret", they should not only be cost-effective and involve co-benefits but also be free of hard negative side effects with other objectives. Yet, almost all guides and CAPs do not clearly state trade-offs and conflicts and explicitly use terms such as "co-benefits" or "multiple benefits" or "ancillary benefits" introducing a positivity bias towards the impacts [29, 34]. In this fashion, CAPs appear to disregard or conceal valuable information. Other scholars have also called attention to the risk of using the co-benefits concept for promoting particular programmes in an opportunistic way [36].

For at least the above-mentioned reasons, municipalities must seek comprehensive coverage of potential co-benefits and co-harms in their prioritization process and overall designing of their CAPs to avoid counterintuitive and biased results [33] as well as locking into high-emission pathways and

unsustainable urban futures [35]. However, conceptual models and integrated approaches to quantifying a wide range of co-benefits are largely lacking [36, 37]. Quantification methodologies are mostly available for the impacts of actions on job creation, air pollution, health (often expressed in reduced number of premature deaths), household savings and road fatalities (e.g. see [33, 38]). To avoid focusing only on impacts that can be quantified and increase the comprehensiveness of sustainability issues considered, cities can qualitatively map all the positive and negative interactions between climate actions and other sustainability objectives (e.g. in a matrix of relationships [35, 39]), and indicate their relevance as positive or negative co-impacts using ordinal scoring methods. Such a method has been used by NYC for prioritising its actions – i.e. a five-scale qualitative system, ranging from "major risk" (score 1) to "major benefit" (score 5) [26]. Eventually, the mapping against co-benefits can also be extended to include the relevant SDGs as a way to combine the implementation of both the Paris Agreement and the Agenda 2030.

5. Conclusions

Cities are viewed more and more as an important object of assessment, and city governments as an important actor group, in the global effort to mitigate climate change. In response to peer pressure, or motivated by internal goals, cities across the globe are increasingly taking responsibility for their climate impact through voluntary commitments to ambitious targets and action. However, although practical and scientifically robust information are available on what type of technologies and climate actions cities can and must employ to reach climate neutrality, the challenge to alter their emissions path while meeting multiple competing priorities is still enormous. As evidenced by surveys, local authorities lack methodological bases with respect to the definition and prioritisation of actions based on certain criteria. In this context, the present paper attempted to provide inspiration for research and practice on how to better support municipal stakeholders in this task. In the identification of possibilities to act, of course, cities can learn from each other's experiences, and normally more efficaciously than they could from scientific literature. The authors argue that research can help improve and accelerate such cross-learning through the development of effective mechanisms to extract case study evidence on innovative solutions and combine it with city typologies. This is only a starting point; each city is unique and the development of case-specific strategies is unavoidable. For the prioritisation of actions, it was pointed out that all stakeholder groups, either belonging to the "producers" or "consumers", must be mobilized and integrated into future municipal concepts for climate protection through actor-specific strategies to exploit the city's full reduction potential – only in few cases the "city authority" is the most important change agent and demand-side mitigation options currently remain overlooked. Finally, it is highlighted that climate mitigation strategies for cities can be more than about climate impact; each action is associated with a host of economic, social, and environmental co-impacts. When actions are compared against each other the presence of co-impacts may influence their rank-ordering. Furthermore, the structured assessment of impacts on health, wealth and other aspects in the interest of local stakeholders can increases the likelihood of engaging more diverse communities of interest (also as investors) in the process and consequently also of the success of a CAP. This also offers an opportunity to combine the top-down level SDG targets with bottom up analysis of what is of interest for the local community. The development of guiding methodologies and practical tools providing a better understanding of the interactions and casual relationships of different sustainability objectives would be necessary in future for an informed decision-making targeted at maximizing co-benefits while minimizing tradeoffs.

References

[1] Hsu A, Widerberg O, Weinfurter A, Chan S, Roelfsema, M, Lütkehermöller K and Bakhtiari F 2018 *Bridging the Emissions Gap: The Role of Non-state and Subnational Actors: Pre-release Version of a Chapter of the Forthcoming UN Environment Emissions Gap Report 2018* (Nairobi: United Nations Environment Programme)

[2] UN-Habitat 2011 *Cities and Climate Change: Global Report on Human Settlements 2011* (London: Earthscan Ltd, UN-Habitat)

[3] Broto V C and Bulkeley H 2013 *Global Environ. Chang.* **23** 92-102
[4] Global Commission on the Economy and Climate 2014 *Better Growth, Better Climate: The new Climate Economy Report* (Washington, DC: World Resources Institute)
[5] Global Covenant of Mayors for Climate and Energy (Online: www.globalcovenantofmayors.org/)
[6] Reckien D, et al. 2018 *J. Clean. Prod.* **191** 207-19
[7] IPCC 2018 *Global Warming of 1.5°C: An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to eradicate Poverty* (Geneva: IPCC)
[8] Ambition to Action 2017 *SDG Climate Action Nexus Tool (SCAN-tool)* (Online: http://ambitiontoaction.net/scan_tool/)
[9] Covenant of Mayors for Climate and Energy 2017 *Covenant Community's Needs for SE(C)AP Design and Implementation* (Available at: www.covenantofmayors.eu)
[10] BBSR and BBR 2017 *CO2-Neutral in Cities and Neighbourhoods: The European and International Perspective* (Bonn: BBSR-Online-Publikation)
[11] Price L, et al. 2016 *Low-Carbon City Policy Databook: 72 Policy Recommendations for Chinese Cities from the Benchmarking and Energy Savings Tool for Low Carbon Cities* (Report Number: LBNL-1006326) (Available at: https://repository.usfca.edu/)
[12] The World Bank 2016 The CURB Tool: Climate Action for Urban Sustainability (Online: http://www.worldbank.org/en/topic/urbandevelopment/brief/the-curb-tool-climate-action-for-urban-sustainability)
[13] ClimateTechWiki (Online: http://www.climatetechwiki.org/)
[14] Covenant of Mayors for Climate and Energy 2016 The Covenant of Mayors for Climate and Energy Reporting Guidelines. Version 1.0 (Available at: www.covenantofmayors.eu)
[15] Covenant of Mayors for Climate and Energy (Plans and Actions, Online: https://www.covenantofmayors.eu/plans-and-actions/good-practices.html)
[16] Brown J, Sako D 2016 Cities100: 100 Solutions for Climate Action in Cities (Copenhagen and London: Sustainia and C40 Cities Climate Leadership Group)
[17] Plastrik P and Cleveland J 2018 *Game Changers: Bold Actions by Cities to Accelerate Progress Toward Carbon Neutrality* ed M Shank and J Partin (Copenhagen: CNCA)
[18] Gregor M, et al. 2018 *Similarities and Diversity of European Cities. A Typology Tool to Support Urban Sustainability* (Vienna: European Topic Centre on Urban, Land and Soil Systems)
[19] Baiocchi G, Creutzig F, Minx J and Pichler P P 2015 *Global Environ. Chang.* **34** 13-21
[20] Creutzig F, Baiocchi G, Bierkandt R, Pichler P P and Seto K C 2015 *PNAS* **112** 6283-6288
[21] Urban Climate Change Research Network *Case Study Docking Station* (Available at: http://uccrn.org/case-study-docking-station-overview/)
[22] Hendriksen B, Peereboom E C, Ballantine J, Wielaard N, Jansen S 2010 *City Typology as the Basis for Policy* (Available at: www.kpmg.de/docs/city_Typology.pdf)
[23] Zoeteman K, van der Zande M and Smeets R 2015 Integrated Sustainability Monitoring of 58 EU-cities (Tilburg: Telos)
[24] International Organization for Standardization 2018 *ISO 37120:2018: Sustainable Development in Communities: Indicators for City Services and Quality of Life* (Geneva: ISO)
[25] C40 Cities and Arup 2016 *Deadline 2020* (Available at: www.c40.org/other/deadline_2020)
[26] The City of New York 2017 *1.5°C: Aligning New York City with the Paris Climate Agreement* (Available at: https://www1.nyc.gov/site/sustainability/codes/1.5-climate-action-plan.page)
[27] Watts M, et al 2015 *Climate Action in Megacities 3.0* (London: C40 Cities Climate Leadership Group & Arup)
[28] Azevedo I, Delarue E and Meeus L 2013 Energy policy **61** 894-900
[29] Balouktsi 2019 Crafting local climate action plans: An action prioritisation framework using multiple criteria decision analysis (accepted paper for SBE19 Graz)

[30] Balouktsi M 2018 Principles and Tools for Designing Strategies for Sustainable Urban Development: A "Process-based" and "Action-oriented" Approach at Neighbourhood Level (Karlsruhe: Karlsruhe Institute of technology) PhD Thesis available at: https://publikationen.bibliothek.kit.edu/1000088490
[31] McKinsey Center for Business and Environment and C40 Cities 2017 Focused Acceleration: A Strategic Approach to Climate Action in Cities to 2030 (Available at: https://www.mckinsey.com/business-functions/sustainability/our-insights/a-strategic-approach-to-climate-action-in-cities-focused-acceleration)
[32] Ürge-Vorsatz D, Herrero S T, Dubash N K and Lecocq F 2014 *Annu. Rev. Environ. Resour.* **39** 549-582
[33] SSG 2017 *Technical Paper No 4: Considerations of Co-Benefits and Co-Harms Associated with Low Carbon Actions for TransformTO* (Vancouver: Sustainability Solutions Group)
[34] Ruth M, Ghosh S, Mirzaee S and Lee N S 2017 Co-benefits and co-costs of climate action plans for low-carbon cities. In Creating Low Carbon Cities (Springer) pp. 15-28
[35] Ürge-Vorsatz D, et al 2018 *Nat. Clim. Change.* **8** 174
[36] Mayrhofer J P and Gupta J 2016 *Environ. Sci. Policy* **57** 22-30
[36] Amekudzi A, et al. 2014 *Carbon Manag.* **2** 363–365
[37] Mendez, M A 2015 *Local Env.* **20** 637–663.
[38] Day T, et al. 2018 Climate Opportunity: More Jobs; Better Health; Livable Cities 2018 (New Climate Institute, Report available at: https://newclimate.org/2018/09/09/climate-opportunity-report/)
[39] Ferreira M, Almeida M and Rodrigues A 2017 *Energy Build.* **152** 587-601