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Viewpoint
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Introduction

Considerable effort is being directed at securing city-scale climate adaption plans that focus on curbing greenhouse gases (GHGs), efficient resource use and health and social equity, consistent with United Nations' (UN) ambitions of creating resilient sustainable cities (UN-Habitat, 2021). And yet, despite the substantial economic, social and ecological advantages of curbing GHGs, systematic and widely applicable measurements of GHGs are difficult to achieve (Ramaswami et al., 2021). Likewise, and despite continued international pressure, ongoing difficulties surround the widespread adoption of comparable emission reduction targets (https://ukcop26.org/; Wei et al., 2021). Implementation is further complicated given that cities cohere from vibrant assemblies of people, goods, communications and investments, which are fused together across international space-time (Sassen, 2012). Therefore, while cities often represent important entrepots for innovative GHG mitigation strategies, considerable financial, institutional, socio-economic and political barriers can encumber widespread application (Karimipour et al., 2021).

The following commentary provides possible ways forward on these issues, by concisely outlining the strengths and weaknesses of different GHG accounting methods and scopes of emissions relevant to urban areas (Ramaswami et al., 2021), before setting out possible governance improvements required to create truly sustainable cities. Drawing inspiration from recent internationally significant public-private efforts to protect tropical forests at jurisdictional scale (https://leafcoalition.org/), this short piece then presents one possible model for the creation of a coalition of sustainable cities, a coalition that represents a multi-sector-based approach to GHG reductions and which aligns with international endeavours to promote urban sustainable development.

Reducing urban GHGs

Although cities have a long association with unremitting movement – for example, the circulation of trams, cars and trains, flows of electricity through cables or the 'hustle-and-bustle' of people – there is a growing sense that contemporary urban spaces are being irrevocably shaped by innumerable global connections which are intertwined

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across international space/time (Sassen, 2012). Advanced logistics networks, increasing migratory streams and the circulation of information via communication technology has arguably intensified the role of cities as being key articulators of mobility made up of complex bundles of spatial forms (Egerer et al., 2021).

Most cities therefore contain a mesh of sometimes complex and overlapping human and non-human relations. These involve 'stretched-out' historical and spatial relationships within larger-scale ecological, socio-economic, political and infrastructural systems (Adams et al., 2020). For example, cities often make significant calls on resources that are imported from great distances: food, water, transportation fuels, electricity and construction materials are all required to sustain urban populations (Ramaswami et al., 2021). Economic linkages and the movement of goods, commodities and services also move embodied carbon through international networks which inevitably spill over geographically bounded nation-state jurisdictions with relative ease.

Given that the contemporary world has arguably fewer fixed borders acting as impediments to movement and connectivity, applying comprehensive and locally applicable GHG accounting at the city scale presents considerable challenges for those actors involved in the design and management of sustainable cities (Mueller et al., 2021). That said, multiple approaches seek to measure and monitor GHGs from 'private and public sector operations, value chains and mitigation efforts' (see the ICLEI-USA Community GHG Protocol (GHG) and the Global Protocol for Cities [GPC]; https://ghgprotocol.org/). For example, defining different territorial emissions according to 'scopes' underpins the widely applied GHG Protocol. In this case, Scope 1 captures those emissions generated from sources situated within urban limits, including stationary energy, transportation and waste, together with non-energy GHGs from local industrial processes, agriculture/forestry and land-use change. These are recorded via measures of fuel-use as reported in local and national sources (https://ghgprotocol.org). Pursuing Scope 1 reductions presents important opportunities for different urban actors, including planners. Hence a careful review of land-use patterns, urban fabrics and an examination of the historical–geographical interplay between aspects of the urban morphological frame (the pattern of streets, plots and buildings) would certainly have a role to play in reaching policy-based decisions on how to reduce Scope 1 emissions (Table 1) (Thomson and Newman, 2021).

Likewise, planning frameworks can help to recognise the 'green' potential of stalled, latent or underutilised sites. These spaces, alongside other biophilic, nature-based and technologically informed approaches, offer further scope for urban stakeholders to integrate GHG reduction measures; and such efforts may deliver much-needed socio-economic benefits and improve individuals' physical and mental well-being (Egerer et al., 2021; Sivak et al., 2021). Technological improvements in atmospheric gas monitoring and remote sensing have also revived evaluations of Scope 1 GHG accounts in cities; and further improvements, if mainstreamed, may provide clear pathways for wider-scale application (Mueller et al., 2021). Despite these benefits, Scope 1 approaches suffer because of their geographical 'boundedness' and focus on the city scale; hence they largely fail to capture substantial emissions flowing through infrastructural networks into cities (Karimipour et al., 2021). Therefore, while planning frameworks are well placed to tackle Scope 1 reductions through the use of place-based instruments, too much emphasis on land-use planning interventions, sector-specific issues, and bounded notions of scale runs the obvious but dangerous risk of ignoring how cities function across expansive networks of connection (Sassen, 2012; Scott et al., 2013).

Table 1 Urban decarbonisation approaches and tools for implementation

Decarbonisation approach	Applied examples	Tools / mechanisms
Scope 1 Assessing location-specific, territorial accounting	Few cities apply Scope 1. Though improvements in technology and monitoring may lead to wider adoption (Mueller et al., 2021)	**Net-zero location-based emissions.** Reduced fuel combustion; vehicle efficiencies; SMART transport systems; improved infrastructure; improving energy production and waste management approaches (Karamipour et al., 2021) Other initiatives include promoting energy audits; retrofitting across residential, commercial and institutional buildings; decreasing 'unnecessary' construction/demolition; co-location of housing and employment; creation of green infrastructure/biophilic/farming approaches across different urban fabrics (Karamipour et al., 2021; Thomson and Newman, 2021; Weil et al., 2021)
Scope 2 Community-wide supply-chain accounting across key multi-sector 'provisioning systems' (energy, mobility, water, waste management, green infrastructure and food systems)	~30 cities have adopted Scope 1 and 2, although ~90 cities have adopted 'basic' or 'advanced' international protocols for Scope 1 + 2 and 3 across certain provisioning systems (Nagini et al., 2019)	**Net-zero carbon community-wide infrastructure.** Move towards sustainable green energy supplier or 'upstream' sourcing of renewable electricity, gas, heating and so on. Generation of on-site renewables, roll-out of 'green' power programmes, for example
Consumption-based analysis of consumer expenditures	Household-based consumption calculators, though these exclude data from exporting businesses	**Net-zero household expenditures.** Key behavioural data on household preferences: this can inform local or spatially nested policy decisions targeted at reducing GHGs (dietary changes, incentives for increased 'green' consumer behaviour) (Jones and Kammen, 2011)

Decarbonisation approach	**Applied examples**	**Tools / mechanisms**
Scope 3+ Total supply-chain accounting and local-to-global trade connections (i.e. beyond the key provisioning systems)	~80 cities, though doubts re: paucity/reliability of high-quality input-output data in some cities (Wiedmann et al., 2020)	**Moving beyond community-wide approaches.** Petroleum refining, improved water supply and wastewater treatment systems, use of sustainable construction materials, reviewing transboundary agricultural emissions for food chains, alongside biogenic carbon from land-use change/ sequestration using green infrastructure (Ramaswami et al., 2021) Create net-zero carbon trade, facilitated by sophisticated input-output modelling/ auditing, and/or use of three dimensional imaging, advanced remote sensing/satellite data (Mahta et al., 2019)

Source: Adapted from Ramaswami et al. (2021)

A focus on reducing locally produced emissions therefore remains worryingly troublesome, especially as infrastructure supply chain GHG reporting is difficult to capture (Karimipour et al., 2021). There is hope, though. Implementable community-scale protocols have also emerged and these Scope 2 approaches better reflect a more transborder interpretation of urban time/space (Ramaswami et al., 2021). In this sense, then, Scope 2 measures capture the emissions created during the production of energy; these represent indirect imports of emissions emanating from grid-supplied electricity, heat, steam and/or cooling (Karimipour et al., 2021) (Table 1).

While these developments are encouraging, a more comprehensive, far-reaching Scope 3 approach seeks to capture all other GHG emissions associated with wider 'value chain' of productive activities, including the provision of shelter, water, building materials, food, green public spaces, energy and mobility–connectivity systems from outside urban boundaries (Wiedmann et al., 2021). Moving beyond Scope 1 and 2 therefore represents an important international policy goal; and an emphasis on these key sectors is internationally significant, as they contribute >90 per cent of global GHG emissions (Ramaswami et al., 2021) and hence are central to endeavours to create resilient net-zero sustainable cities (UN-Habitat, 2021). On the consumption side, the size and composition of carbon footprints can be measured using GHG emissions from the production of all goods and services, wherever they occur globally to final consumption in households across city jurisdictions. This is especially valuable in helping to shape policy interventions that influence 'behaviour change at a household level' (Jones and Kammen, 2011, 4088). In turn, tailored responses to different urban populations would emerge, encouraging a shift in dietary choices or fostering the take-up of urban agriculture, for example (Table

1). These are positive moves. But certain industrial and service-level energy consumers are excluded from the counts; this reduces the potential effectiveness of global accounting protocols that seek to monitor hybrid urban interconnections and instil community-wide GHG measures (Ramaswami et al., 2021).

There are grounds for optimism, though. Advances in sophisticated input-output accounting, enabled by technological improvements in data collection/processing, and improved city-scale inventories offer possible avenues for capturing Scope 3+ supply chain emissions of urban activities (Wei et al., 2021) (Table 1). These developments hold tremendous promise in securing transborder ambitions of decarbonising urban systems (Wiedmann et al., 2021, 13). For example, advances in input-output modelling, using blockchain technology to measure cross-boundary carbon flows offer hope in this regard. Equally, improved remote sensing of thermal combustion, satellite data of electricity use, locational mobile phone data and innovative three-dimensional imaging of urban change provide inventive ways to mainstream community-wide Scope 1+2+3+ GHG accounting (Mahta et al., 2019).

Mechanisms and protocols that set out to reduce or even reverse GHG emissions can bring considerable economic, social and ecological benefits for societies and ecosystems. While this may be the case, questions continue to surround the implementation of common GHG emission reduction frameworks (Karamipour et al., 2021). And concerns are raised over whether the appropriate forums are in place to support successful dialogue between networks of practitioners, policy makers, researchers and diverse communities across different cities (Sykes et al., 2021).

Creating an urban coalition

Clearly, cities vary in their complexity; and decision-making power, resources, political willingness, social, cultural and demographic differences, together with differing priorities all impact the effectiveness of climate change mitigation/adaptation measures (Egerer et al., 2021). Similarly, a paucity in reliable, expediently collected and comprehensive GHC data remain problematic, while fragmented approaches to local accounting are common barriers to extensive adoption (Mueller et al., 2021, 2). Likewise, technological innovations designed to measure, halt or reverse GHG emissions may not align with other social and/or environmental goals. Engineering a spirit of state–city collaboration may prove difficult, too, especially given recent moves by leaders of some nation-states to question the value of multilateralism by pursuing narrowly defined national interests (World Economic Forum, 2020). Potential solutions to these challenges are especially pressing considering the coordinated support needed to develop COVID-19 recovery plans, and the need to balance urban development and economic growth, while delivering long-term ecological/environmental commitments (United Nations Environment Programme, 2021).

Despite these anxieties, cities can also exert powerful distributed or networked forms of diplomacy and entrepreneurship; when harnessed, influential urban coalitions hold a key role in empowering different state and non-state communities in designing and demonstrating possible climate solutions (Wekesa, 2021). And while several important international public–private networks promote climate change mitigation and adaptation, there is further scope to share knowledge, create meaningful global commons, governance structures and positive urban frameworks (Egerer et al., 2021). Indeed, despite varying sectoral coverage and success, city-level GHG emission inventories have been developed in many countries (Wei et al., 2021), and standardised Scope 1 and 2 protocols are in place for some cities in Europe, the United States and Asia (Nangini et al., 2019) (Table 1). Having these measures in place suggests that moving to Scope 3+ offers grounds for optimism.

Seeking inspiration from recently adopted innovative, coordinated public and private initiatives may also help to enable implementable 'climate smart' cities (Wekesa, 2021). For example, potentially valuable 'urban' lessons could emerge from the recently created 'Lowering Emissions by Accelerating Forest Finance' (LEAF) coalition (https://leafcoalition.org/). In brief, by using price guarantees to pay at least $1 billion in public and private finance, this coalition sets out to tackle uncurbed deforestation and degradation in ways that meet the climate goals of the 2015 Paris Agreement, particularly in developing and tropical countries (https://leafcoalition.org/). Participant jurisdictions (nations, individual states and provinces) wishing to protect 'their' forests can apply to the coalition on a voluntary basis, thereby demonstrating progress towards fulfilling nationally determined contributions as set out under the Paris Agreement. Finance is directed at participating jurisdictions and targeted at high-quality forest-based emissions reductions. Before credits and payments are issued to participants, an independent party must verify the results of territorial nature-based solutions using the UN-supported Reducing Emissions from Deforestation and Forest Degradation (REDD+) 'independent standard' (https://www.artredd.org/trees/) (Seymour, 2020). Satellite data, artificial intelligence and other remote sensing technology will monitor the effectiveness of forest conservation efforts.

Although this initiative has been widely interpreted as a laudable endeavour, concerns are raised over the social and environmental integrity of land-based emissions reduction credit-based systems, and how they apply in ecologically diverse and environmentally sensitive areas (Seymour, 2020). There are concerns, too, about how certain companies, insurers, banks and other institutions seek to boost their 'green' credentials through participating in the initiative while continuing to invest in polluting supply chains (Hodgson and Nauman, 2021). Similarly, there are questions of jurisdictional extent and the timescales involved with delivery, and the role of indigenous community perspectives in shaping these ambitions (Seymour, 2020).

These and other issues would doubtlessly apply if a similar LEAF-style approach was proposed for complex urban contexts. And yet, with sufficient financial support, societal consensus and political will, there are calls for similar coalition of interested parties to develop integrated climate-based solutions across spatial and social scales (Egerer et al., 2021). Indeed, governments, companies, insurers, banks, research communities and civil society groups are being strongly encouraged to ensure coordinated and financially supported emissions reduction plans which have applicability across different urban jurisdictions (UN-Habitat, 2021). When set against a backdrop of improved GHG emission reduction protocols and city networked power, unpicking the principles of the LEAF coalition could offer valuable hope for other large-scale multi-sectoral approaches.

In following the broad parameters of the LEAF coalition, therefore, what follows is a broad description of a possible urban coalition of sustainable cities (Figure 1). An initial step for this collective might involve creating a taskforce or similar comprising practitioners with different technical knowledge; members could include atmospheric scientists, ecologists, engineers and those drawn from relevant social sciences, including collaborative planners armed with a grounding in international approaches to integrated resource efficiency and/or ecologically informed, sustainable urban planning (Adams et al., 2020). This group (or groups) would consult with the relevant local stakeholders of potential participant cities that are seeking to slow, halt or reverse GHG emissions.

Recognising the advantage of adopting a transboundary approach, the taskforce would: 1) have an overall responsibility for identifying the context-specific opportunities and constraints involved with helping to realise Scope 1+2+3+ emissions reductions; 2) review the relevant land-use regulations, together with transdisciplinary, co-creative stakeholder instruments needed to achieve sectoral emissions reductions; 3) discuss the technological implications/timescales involved with generating accurate, reliable, regular usage-activity data, possibly via the application of sophisticated input-output modelling that tracks supply chain GHG emissions; and 4) assess sustainable models of land ownership/stewardship and participation to reduce (perceived) risk and increase the number of investable projects. Participant cities would strategically focus on key provisioning systems (energy, mobility, waste, water, food, buildings and public/green space), which represent important stages towards creating a net-zero carbon and equitable future (Ramaswami et al., 2021). Information on possible sectoral mitigation and adaptation measures should be included relating to the reduction potential and the relative abatement cost for the main producers of urban GHG emissions across the seven sectors (Karimipour et al., 2021) (Figure 1).

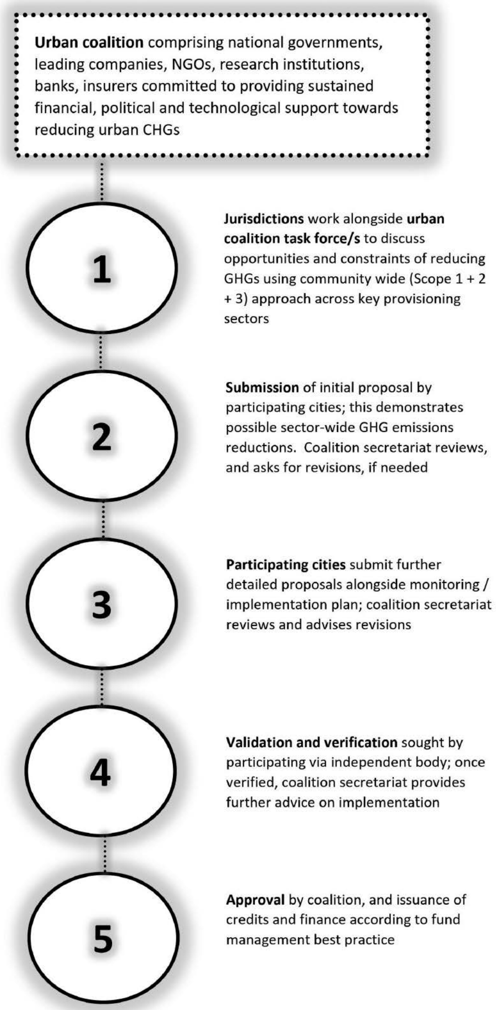

Figure 1 Outline of proposed urban coalition to reduce urban GHGs

Acknowledging the uniqueness of each urban system would also require careful consideration. Therefore, thought should be given to the perspectives of different city dwellers; their use of different urban fabrics and services is fundamental in shaping priorities of interventions that both respect indigenous knowledges and acknowledge the often-complex relationship between diverse human-nature ecosystems (Thomson and Newman, 2021). Following these discussions, participant cities would be encouraged to submit an expression of interest to the coalition for review; this could include a description of the relevant legal authority (jurisdiction), and a summary of the organisations, groups and individuals will assist with project delivery (government agencies, consultants, universities, NGOs, service providers, communities, and so on) (Figure 1).

In line with the provisions set out by the LEAF coalition, this information would be accompanied by approval from the relevant national government (in accordance with each state's commitment to delivering nationally determined contributions); and a description of how rights were obtained in accordance with domestic law (i.e. resource right holders/landowners) (https://leafcoalition.org/). An implementation plan and monitoring report would be required, alongside a conformance summary that clearly outlines how indigenous community voices have shaped the proposal in ways that align with robust social and environmental governance safeguards (Egerer et al., 2021). Issues of 'leakage' (whether emissions reductions in one place cause increases elsewhere), 'additionality' (whether reductions would have happened even without a particular intervention), and 'permanence' (whether a reduction at one point in time is reversed at another) requires careful monitoring, despite the promise of Scope 1+2+3+ accounting. The coalition secretariat would review the information. Again, as per the LEAF example, participant cities then select an independent body to verify and validate the proposals. Once approved, and agreed by the coalition's secretariat and board, credits are issued. Performance would be measured against accepted international standards, and capital is released as reduction targets are met (Figure 1).

Ways forward

Several cities have clear and implementable climate targets and there are significant networks of public–private interests that are committed to planning for sustainable urban development that accords with the UN's Sustainable Development Goals. These are encouraging signs. But further opportunities also lie ahead for planners to engage with ongoing discussions on how to measure community-wide, sector-based urban GHG reductions when cities and urban areas are inevitably shaped by transboundary spatial connections. Advances in technology, data science and measurements are fundamental to realising sustainable urban transitions, though complex urban processes also require careful analysis. Clearly, the ideas presented in this short commentary are highly experimental and speculative. And yet, this article does make a tentative effort to apply some of the key concepts embedded in the recently adopted international, multi-stakeholder initiative to an urban context. In so doing, the suggested framework presented here responds directly to calls for innovative and potentially implementable frameworks that encourage wider cooperation among governments, business communities, social organisations and other stakeholders to take climate action (Wekesa, 2021). This is an essential and urgent step, as some see it, towards the creation of scalable jurisdictional approaches for GHG emission reductions and sustainable cities of the future.

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