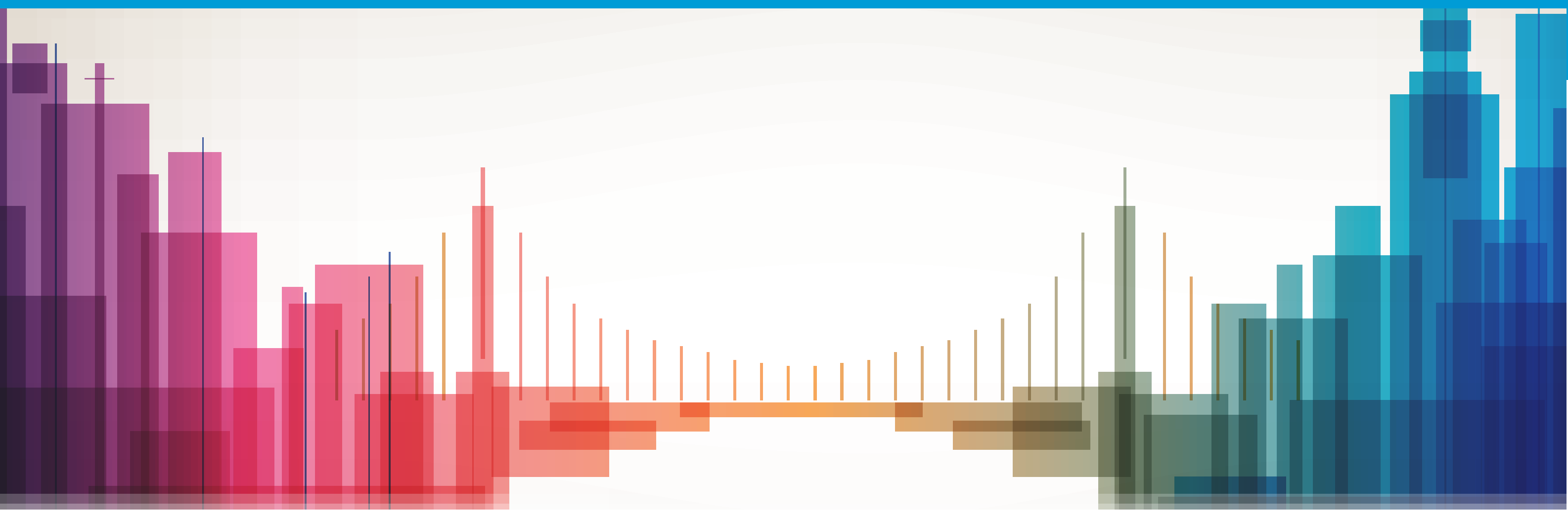
U4SSC

Methodology to assess Net Zero progress in cities



Convention on Biological Diversity
United Nations ECLAC
Food and Agriculture Organization of the United Nations
UNIDO
ITU
UNDP
United Nations Economic Commission for Africa
UNECE
UNESCO United Nations Educational, Scientific and Cultural Organization
UN environment programme
UNEP FINANCE INITIATIVE
United Nations Framework Convention on Climate Change
UN-HABITAT FOR A BETTER URBAN FUTURE
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Foreword

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Disclaimer

The opinions expressed in this publication are those of the authors and do not necessarily represent the views of their respective organizations or U4SSC members. In line with the U4SSC principles, this report does not promote the adoption and use of Smart City technology. It advocates for policies encouraging responsible use of information and communications technologies (ICTs) that contribute to the economic, environmental and social sustainability as well as the advancement of the 2030 Agenda for Sustainable Development.

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Abbreviations and acronyms

BSC	Balanced Scorecard
CAGR	Compound annual growth rate
CO_2	Carbon dioxide
EU	European Union
GHG	Greenhouse gas (emissions)
ICT	Information and communication technologies
KPI	Key Performance Indicator
NDCs	Nationally determined contribution

Executive summary

With the ever-increasing need to combat climate change and its impacts (Sustainable Development Goal 13), cities are increasingly turning towards sustainable solutions to reduce their carbon footprint. Digital technologies and information and communication technologies (ICTs) have emerged as key players in this transition, offering various innovative solutions to help cities achieve their goal of becoming Net Zero. However, the adoption and integration of digital technologies in cities is not without its challenges.

This guide on Methodology to Assess Net Zero Progress in Cities aims to provide a comprehensive framework for cities to evaluate their advancement toward achieving Net Zero carbon emissions. This guide emphasizes the importance of data-driven decision-making, continuous monitoring and evaluation to track progress and identify areas for improvement.

This guide comprehensively assesses carbon performance in numerous critical areas, including a GHG emission analysis in the following sectors: buildings, business and labour, transportation, public lighting, water and sewage treatment, waste chain operation, telecommunication networks and land use.

This guide applies the methodology to assess carbon neutrality progress in various cities worldwide, including cities in the United States, European Union, Japan, China and India. This methodology generates a common understanding of how carbon neutrality can be established in cities and how digital transformation is associated. The findings from the methodology generate valuable inputs for city leaders and stakeholders to evaluate and monitor their strategic implementation for local carbon neutrality.

Overall, the Methodology to Assess City Net Zero Progress is a valuable resource for cities seeking to take action on climate change and reduce their carbon footprint. By following the methodology outlined in this guide, cities can better establish a clear pathway towards Net Zero and ensure their efforts are effective and sustainable over the long term.

1 Introduction

Cities are at the forefront of the global effort to address climate change and reduce greenhouse gas (GHG) emissions. With more than half of the world's population living in urban areas, cities are responsible for significant global emissions and play a critical role in achieving sustainability and Net Zero carbon. To this end, many cities worldwide have set ambitious targets to achieve Net Zero carbon emissions by 2050 or earlier.

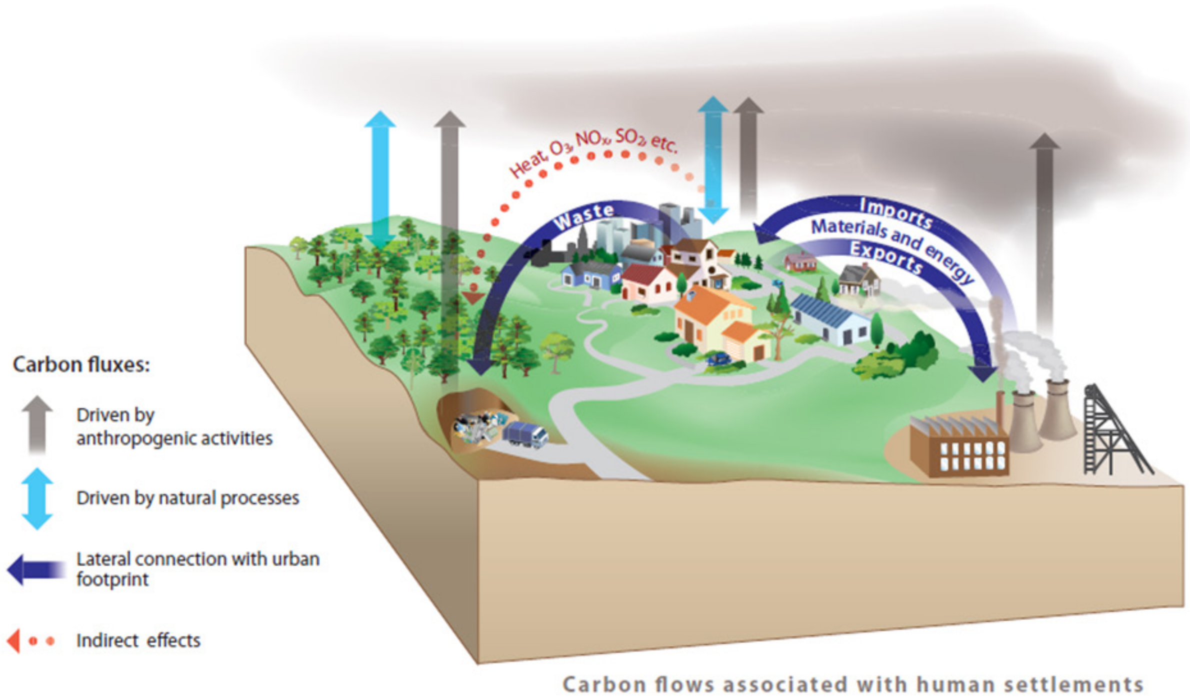
Achieving Net Zero emissions requires a comprehensive approach that involves reducing emissions in numerous sectors. The path to Net Zero is complex, and cities face multiple challenges and barriers. To overcome these challenges and ensure that Net Zero efforts are effective, cities need to develop a robust methodology for assessing their progress. This methodology provides a robust framework for continuous monitoring and evaluation to track progress and identify areas for improvement.

2 Background – understanding carbon flows in cities

Understanding carbon flows in cities is essential for implementing Net Zero methodologies because it provides a clear picture of where emissions are generated and where reductions can be most effective. By analyzing carbon flows across various sectors such as transportation, buildings, energy, and waste, cities can target specific areas for carbon reduction and prioritize actions that yield the highest impact.

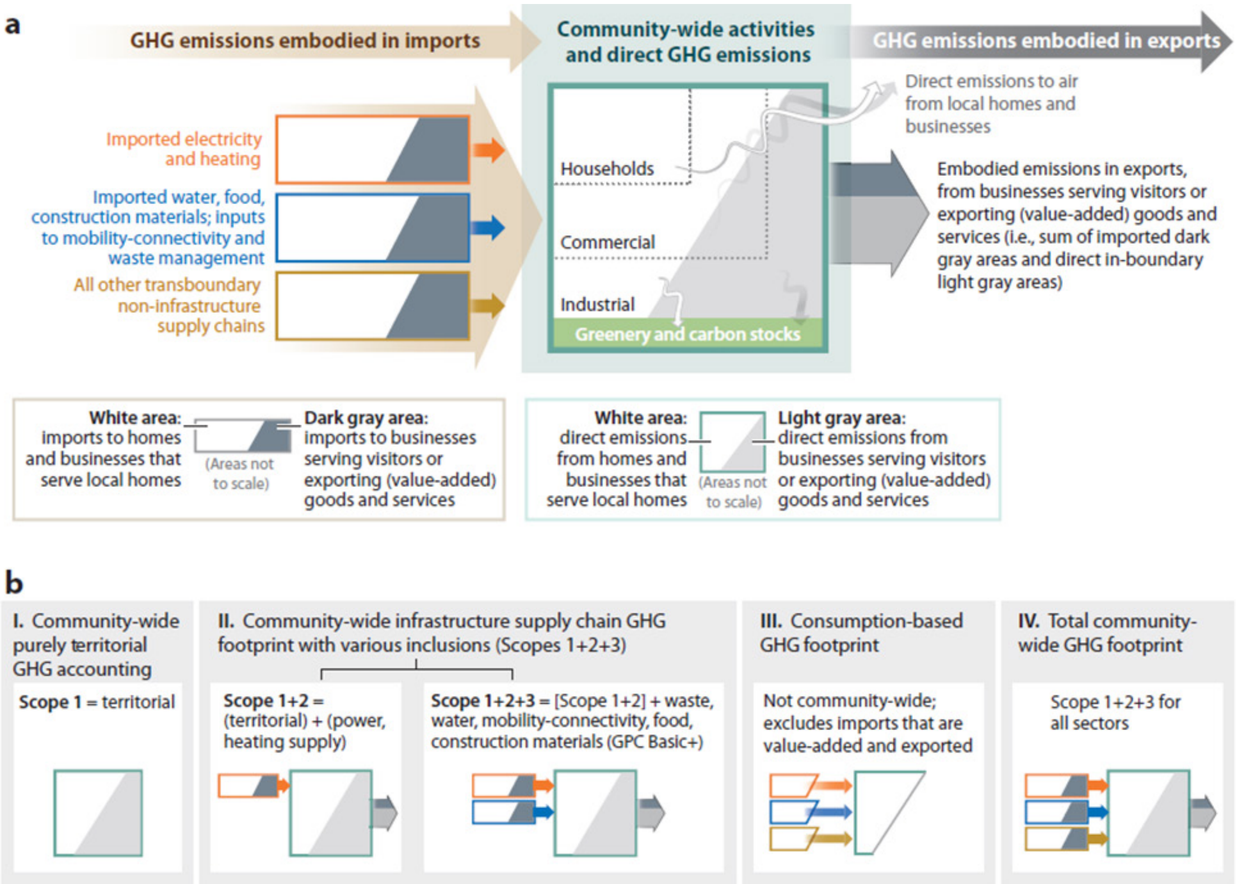
The physical flow of carbon within a city and its activities can be depicted in (Figure 1), while (Figure 2) demonstrates how urban GHG accounting tracks the GHGs (CO_2, CH_4, and N_2O emissions are represented in CO_2 equivalents) embodied in the flow of goods and services in and out of cities, as well as carbon sequestered or released from stocks within cities.

Figure 1: Urban carbon cycle and its linkages with urban footprint (Seto et al., 2021)



In Figure 1, carbon flows are associated with urban activities (residential, commercial, and industrial) and mapped to four urban carbon accounting frameworks (numbered I to IV) (Seto *et al.*, 2021). White areas show carbon emissions (direct and embodied) associated with homes, including emissions from local commercial and industrial business activities that serve local homes. Gray areas show emissions (direct and embodied) associated with commercial and industrial business activities that either serve visitors or export to other communities; lighter and darker shades of gray distinguish between direct emissions and emissions embodied in imports associated with the exporting businesses (Seto *et al.*, 2021).

Figure 2: In-boundary and transboundary carbon flows (Seto et al., 2021)



In Figure 2, different perspectives for Net Zero carbon city measurement and development are depicted:

I. **From a territorial perspective**, a Net Zero carbon city aims to eliminate all carbon emissions produced within the city's administrative boundaries. This could be achieved, for instance, by moving emission sources out of the city's administrative boundaries (which is not desirable) or by incorporating more carbon sinks, such as planting trees (Figure 2). Additionally, some territorial emissions, like the ones associated with airports or harbours, are not controlled by the local Government and corresponding urban policies (Seto *et al*., 2021).

Community-wide infrastructure supply chain GHG footprinting expands on territorial accounting to incorporate GHGs along supply chains of key community-wide infrastructure and food provisioning systems that support all the local activities (residential, commercial and industrial). Cities aiming for systemic infrastructure transitions—such as compact urban development and energy efficiency, which reduce demand for energy and materials—often adopt a community-wide infrastructure supply chain footprinting approach (Seto et al., 2021). In the United States, ICLEI (2021) and the World Resources Institute (WRI, 2004) have introduced greenhouse gas (GHG) accounting protocols. These protocols define GHG emission sources, present methods and tools for calculating emissions (e.g., formula (1)), and establish principles for data collection.

$$GHG\ emissions = Activity\ data \times Emission\ factor^{1} \qquad (1)$$

II. From a community-wide infrastructure supply chain footprint a Net Zero carbon city implies Net Zero emissions for some or all the seven provisioning systems (which are associated with the approximately 90 per cent of global GHG emissions): *energy supply, mobility, construction materials, waste management, wastewater treatment, food systems, and the carbon sequestration benefits of vegetation*. Most current plans for a Net Zero carbon city focus on mobility, buildings and energy systems, while others include waste (Seto *et al*., 2021). This approach excludes local operational energy use by businesses (e.g., hotels, restaurants, industries) that serve tourists or export goods and services elsewhere.

Consumption-based GHG accounting expands the seven key provisioning sectors by assigning source-based GHG emissions from all sectors of the economy, wherever they occur, regardless of the territory, to final consumption by households and governments within a city (Seto *et al*., 2021).

III. From a consumption-based perspective a Net Zero carbon city implies that all households and government expenditures are Net Zero.

Total community-wide GHG footprinting is an emerging approach that includes upstream and downstream supply chain emissions associated with all community-wide activities, i.e., including local and final consumption by households, government, and exports (Seto *et al*., 2021).

IV. From a total community-wide supply chain footprint a Net Zero carbon city would imply that not only imports to local households but also exports from local businesses are Net Zero. This will require global governance of carbon embodied in trade, inside and outside cities, which goes beyond the boundary of a city (Seto *et al*., 2021).

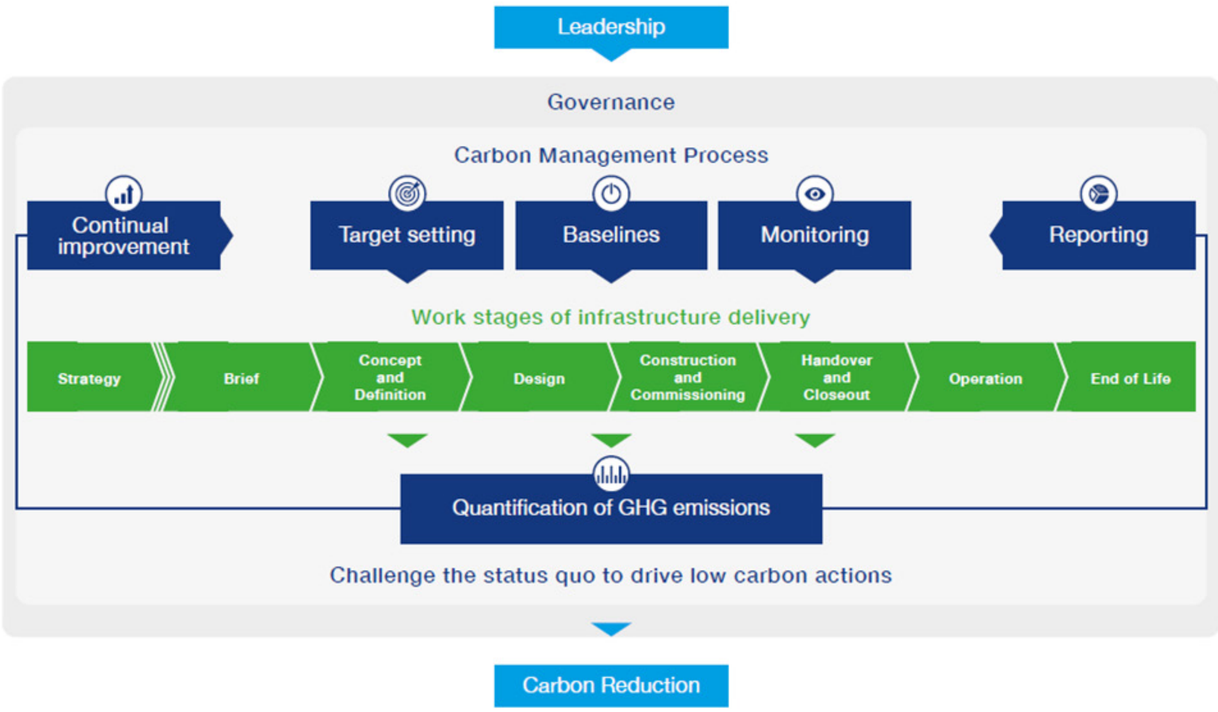
[1] Activity data is a quantitative measure of a level of activity that results in GHG emissions taking place during a given period (e.g., volume of gas used, kilometers driven, tons of solid waste sent to landfill). An emission factor is a measure of the mass of GHG emissions relative to a unit of activity. For example, estimating CO_2 emissions from the use of electricity involves multiplying data on kilowatt-hours (kWh) of electricity used by the emission factor ($kgCO_2/kWh$) for electricity, which will depend on the technology and type of fuel used to generate the electricity (ICLEI, 2021).

3 Assessment Methodologies

3.1 "Carbon-performance" assessment

This methodology aims to calculate the GHG emissions produced and the carbon consumption performance, respectively. In general, both methods consider a carbon management process, like the one identified by existing standards (i.e., PAS 2080, (Construction Leadership Council, 2019)) (Figure 3). This process considers the entire lifecycle of a product or service and provides a framework for managing and reducing carbon emissions across the entire lifecycle of buildings and infrastructure reflecting their interdependencies and the need for a holistic approach to decarbonization.

Figure 3: PAS 2080 Carbon Management Process (Construction Leadership Council, 2019)



3.1.1 GHG emissions by sector

GHG emissions are typically categorized by sector to identify sources and target areas for reduction. Urban areas often focus on reducing emissions from buildings, transportation, and waste, while integrating renewable energy solutions for power generation. Rural strategies emphasize land use and agricultural practices. The following city sectors must be calculated for their carbon performance:

1 Buildings (municipal, industrial, commercial and residential).

2 Businesses and labour size (industry, service and farming sectors).

3 Transportation (public and private), which now evolves to an electric vehicle (EV) charging network.

4 Public lighting (street and open space lighting, fountain operation).

5 Water and sewage treatment and distribution.

6 Waste chain operation (collection, delivery and processing).

7 Telecommunication networks.

8 Land uses.

The following formula can be used to calculate the produced emissions of a sector:

$$GHG\ emissions = Activity\ data \times Emission\ factor^{2} \qquad (1)$$

Formula (1) can be measured different times for each sector, and the results can be compared to highlight whether the produced emissions have decreased or not.

On the other hand, for a product or service, the produced emission should be calculated based on the entire lifecycle (Figure 1). For instance, for a construction facility product, the following formula (2) depicts the baseline calculation methodology of the produced emission (Construction Leadership Council, 2019):

A = Estimated cost of bridge = USD 5 million

B = Industry average of GHG emissions per USD spent = 0.224 kgCO_2e per USD[3]

$$A \times B = 1\ 120\ tCO_2e \text{ for delivery of the construction product} \qquad (2)$$

Moreover, the European Union (EU) has launched a large-scale initiative called the 100 European Climate Neutral Cities, which has defined specific indicators to measure their performance.

1 *Scope 1 GHG emissions* for the city within the geographic boundary (mandatory from the beginning of the mission). This indicator will be calculated based on the emissions from buildings, industry, transport, waste treatment (solid waste and wastewater), agriculture and forestry, and other activities.

[2] Activity data are a quantitative measure of a level of activity that results in GHG emissions taking place during a given period (e.g., volume of gas used, kilometers driven, tons of solid waste sent to landfill). An emission factor is a measure of the mass of GHG emissions relative to a unit of activity. For example, estimating CO_2 emissions from the use of electricity involves multiplying data on kilowatt-hours (kWh) of electricity used by the emission factor (kgCO_2/kWh) for electricity, which will depend on the technology and type of fuel used to generate the electricity (ICLEI, 2021).

[3] The value of each USD is different for each economic sector. For instance, USD 1 for building upgrades contribute differently to USD 1 spent for a car replacement by an electric vehicle.

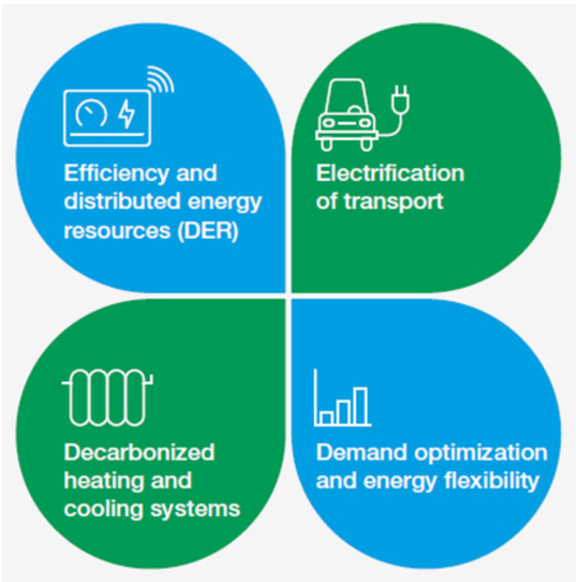
2 *Scope 2 GHG emissions* for the city (mandatory from the beginning of the mission). This indicator will be calculated based on the emissions from indirect emissions due to the production/consumption of grid-supplied electricity within the geographic boundary and indirect emissions due to the production/consumption of grid-supplied heat or cold within the geographic boundary.

3 *Scope 3 GHG emissions* for the city. This indicator will be calculated based on the emissions from out-of-boundary emissions from: the treatment of waste produced within the geographic boundary; out-of-boundary emissions from transmission and distribution of energy consumed within the geographic boundary; out-of-boundary emissions from the transportation of citizens living within the geographic boundary; out-of-boundary emissions from consumption made within the geographic boundary (e.g., food, clothes, furniture, materials); and other indirect emissions.

3.1.2 Carbon consumption maturity model

Inspired by the smart sustainable city (SSC) maturity model that is described in the Recommendation ITU-T Y.4904 "Smart sustainable cities maturity model" (ITU, 2019) the city can be analysed in the following dimensions, according to the integrated approach to a Net Zero carbon city (World Economic Forum, 2021) (Figure 4).

Figure 4: An integrated approach to a Net Zero carbon city (World Economic Forum, 2021)



Energy Efficiency

This dimension is used to evaluate how the energy efficiency has been improved in the city, especially based on the ICT infrastructure. The corresponding topics could be:

- ICT infrastructure
- Energy physical infrastructure
- ICT integration in the energy system
- Energy consumption
- Demand response
- Energy metering
- Energy supply
- Energy management
- Electricity consumption

Mobility electrification dimension

This dimension is used to evaluate the progress of mobility electrification in the city, especially based on the ICT infrastructure. Some corresponding topics could be:

- Public transportation
- Mobility sharing systems
- Private transportation
- Micromobility
- Transportation hubs
- Parking hubs

Systems' decarbonization dimension

This dimension is used to evaluate how city systems have shifted to decarbonization, especially based on the ICT infrastructure. Some corresponding topics could be:

- Renewable energy systems
- Buildings' energy upgrades
- Green buildings
- Circularity for waste processing

- Intelligent building management systems
- Low-carbon emission transportation - carbon emission transportation systems

Energy Demand control dimension

This dimension is used to evaluate how energy demand and general carbon behaviour in the city has changed, especially based on the ICT infrastructure. Some corresponding topics could be:

- Building efficiency
- Behavioural change
- Logistics mobility
- Food systems
- Waste and recycling
- Active mobility

The cities can be classified in maturity levels, addressing corresponding achievements (Table 1):

Table 1: Recommended achievements for each maturity level

	Strategy	ICT Infrastructure	Infrastructure upgrades	Services and utilities	Assessment	KPIs performance
Maturity Level 1	The overall strategy is developed	Key infrastructures and data are identified in the strategy	Key aspects on infrastructure upgrades are identified in the strategy	Strategy and priorities for services and utilities on city level are identified	Assessment plan is ready	Long-term targets for KPIs are set for the city's neutral strategy and baseline values for KPIs are collected
Maturity Level 2	Carbon neutrality initiatives are aligned with the strategy	ICT infrastructures are operated, and corresponding data are produced independently	Methodology to identify and implement upgrades are agreed	Domain services and utilities contribute to carbon neutrality individually	Self-assessment of infrastructure development and services are carried out	Interim KPI targets for maturity level 2 are achieved
Maturity Level 3	Evaluation of carbon neutrality initiatives is carried out	Accessibility of ICT infrastructures and data is improved	Infrastructure upgrades are carried out independently by different sectors.	Services and utilities focus on carbon neutrality and public value generation. Utility and service operation is monitored and analysed to improve carbon neutrality performance	User satisfaction assessments are carried out	Interim KPI targets for maturity level 3 are achieved
Maturity Level 4	Strategy is developed for improving integration and cooperation	Cross-domain ICT infrastructures and data exchanges are provided with interoperability capabilities	Cross-domain infrastructure upgrades are performed	Cross-domain carbon neutrality initiatives	Stakeholders' satisfaction assessments are carried out	Interim KPI targets for maturity level 4 are achieved
Maturity Level 5	Improvement and optimization potential is explored	Continuous development of infrastructure and data provision are carried out	Continuous improvements with state-of-the-art technologies for carbon reduction	Continuous improvements of services and utilities are made by applying advanced state-of-the-art technologies for carbon reduction	Systematic assessment process is established with corresponding actions	Long-term targets for KPIs are achieved

The city will be mapped according to the performance of the identified key performance indicators (KPIs) to maturity levels (Table 2). The table below contains an individual column that measures the ICT performance in the city (digital transformation), based on the ICT implementation efforts and data availability. The model recognizes the importance of digital transformation to carbon neutrality.

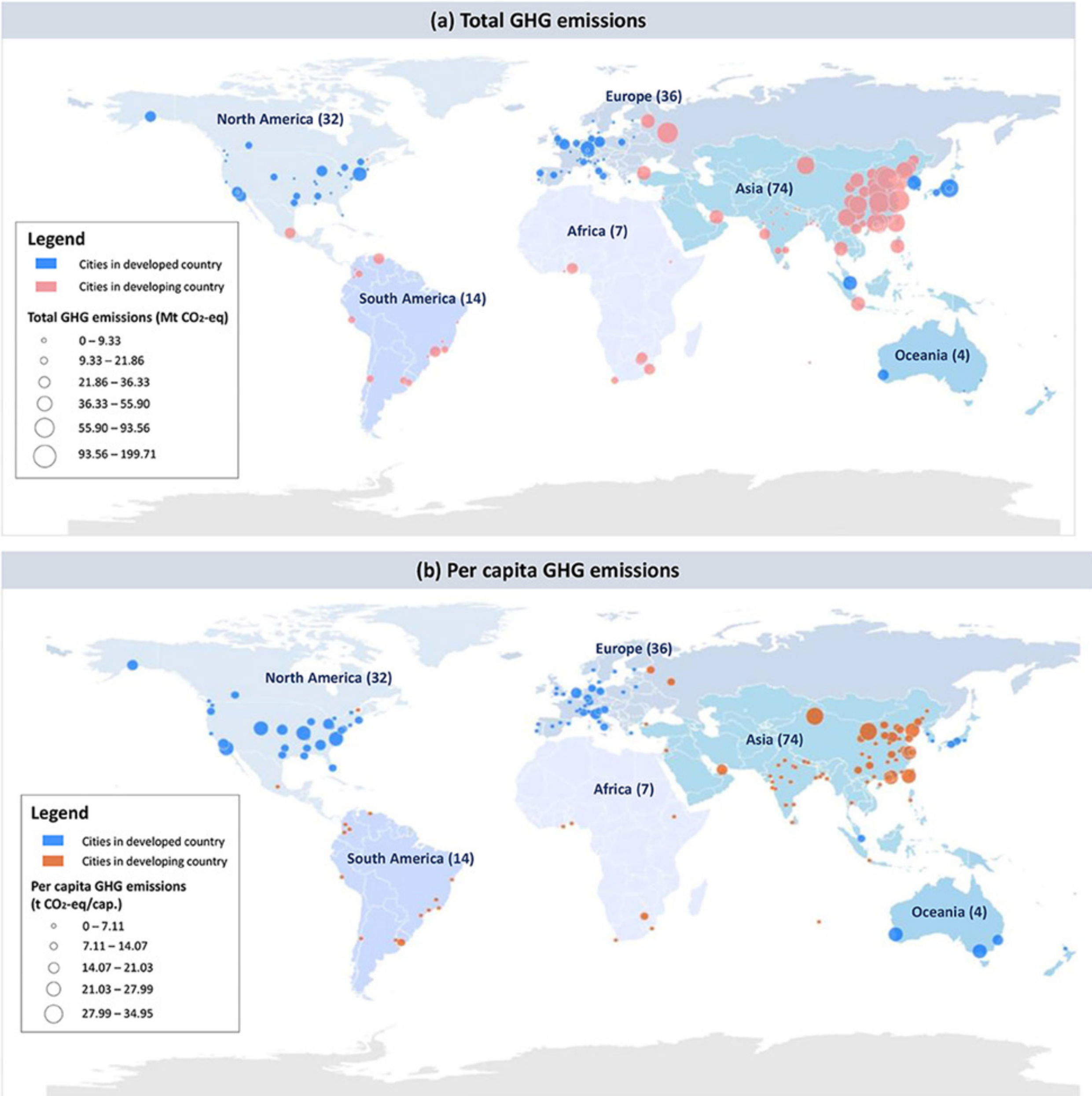
Table 2: Example of performance matrix with target KPI values

Dimension	**Topic**	**KPIs**	**Current KPI value for maturity level 1**	**Interim target KPI value for maturity level 2**	**Interim target KPI value for maturity level 3**	**Interim target KPI value for maturity level 4**	**Long-term target KPI value for maturity level 5**
Energy Efficiency	ICT infrastructure	Household carbon neutral upgrades	Baseline collected	Interim target value e.g., 30%	Interim target value e.g., 40%	Interim target value e.g., 60%	Target value e.g., 80%
		Electricity system based on renewable sources	Baseline collected	–	Interim target value e.g., 30 mins.	Interim target value e.g., 25 mins.	Target value e.g., 15 mins.

3.2 Carbon Neutrality Progress assessment

Wei *et al*. (2021) presents the results of their study concerning the identification of the effectiveness of carbon reduction policies. The study conducted energy-related GHG emission inventories (by eight urban sectors: residential and institutional buildings; commercial buildings; industrial buildings (energy use); industrial process and fugitive emissions; on-road transportation (cars, buses); railways, aviation, and waterways; waste disposal (wastewater treatment, landfills); and other (agriculture and mining) for 167 globally distributed cities, from 53 countries, with information from different sectors. The study assessed the progress of historical GHG emission reduction and the climate targets of global cities in a comparable way.

Figure 5: The (a) total GHG emissions and (b) per capita GHG emissions of 167 cities. The most recent data of cities are shown, which could be in different years (2005–2016), depending on the data availability (Wei et al., 2021)



The total and per capita GHG emissions of the 167 cities are mapped in Figure 5. As shown in Figure 5a, the total GHG emissions ranged between 3.5 kt CO_2-eq and 199.7 Mt CO_2-eq. The top 25 (15%) of the 167 cities accounted for 52 per cent of the total GHG emissions, which are mainly from Asian and European countries. As shown in Figure 5b, the divide of per capita GHG emissions among cities was also huge (ranging from 0.15–34.95 t CO_2-eq/capita). The sector-level emissions of cities around 2012 (108 cities in total) are shown in Figure 6.

Figure 6: Sector contribution to GHG emissions of global cities (Wei et al., 2021)

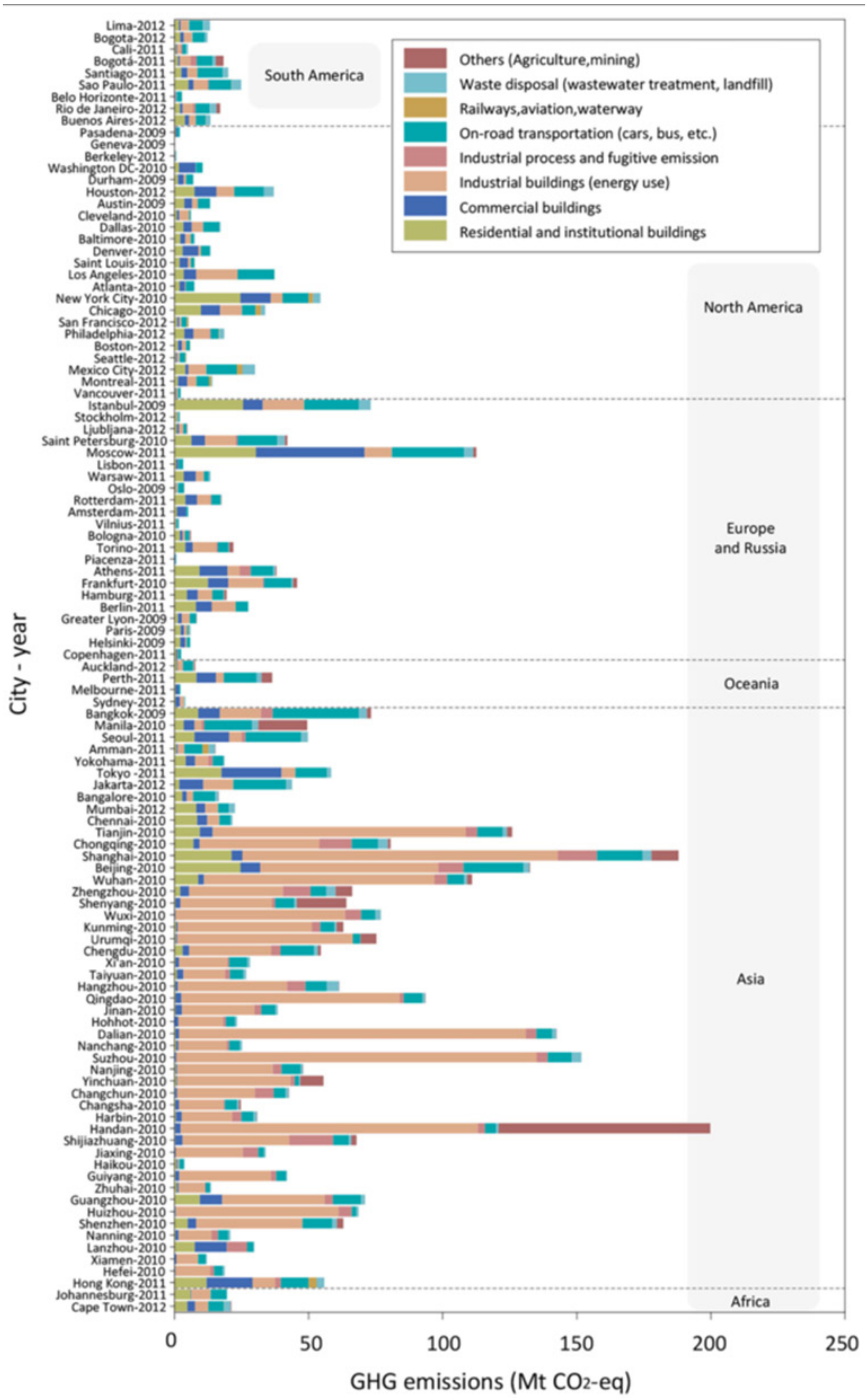


Figure 7 reveals the annual change in total GHG emissions. It shows that 30 cities reduced their annual GHG emissions; many of these are in America and Europe. Figure 7 shows the annual change of capita GHG emissions over the study period in 42 cities that had reliable emission data for at least two years. Seattle (North America), Oslo (Europe), Bogotá (South America), and Houston (North America) are the top four cities with the largest per capita emission reduction (Bogotá is also the second largest city in terms of total reduction).

Figure 7: Annual change of GHG emission in cities over 2005–2016. 1, Yokohama; 2, Vancouver; 3, Stockholm; 4, Paris; 5, Sydney; 6, San Francisco; 7, Milan; 8, Barcelona; 9, Boston; 10, New Orleans; 11, Austin; 12, Washington, DC; 13, Copenhagen; 14, Athens; 15, L

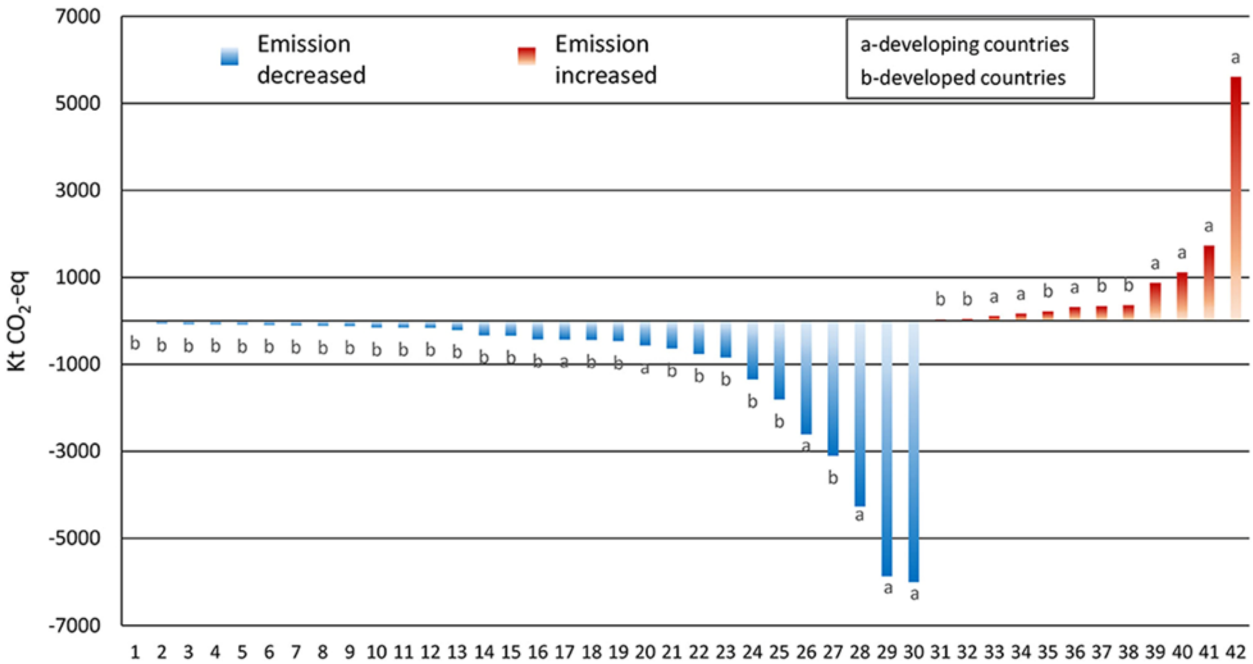
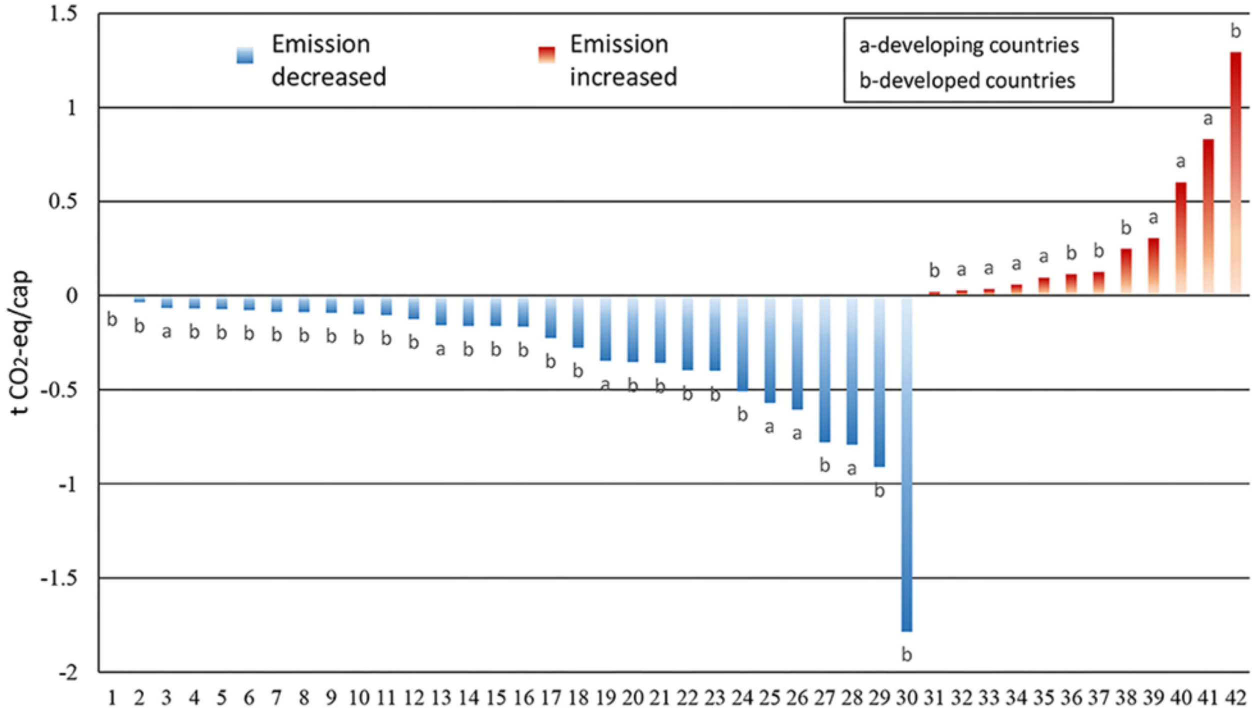
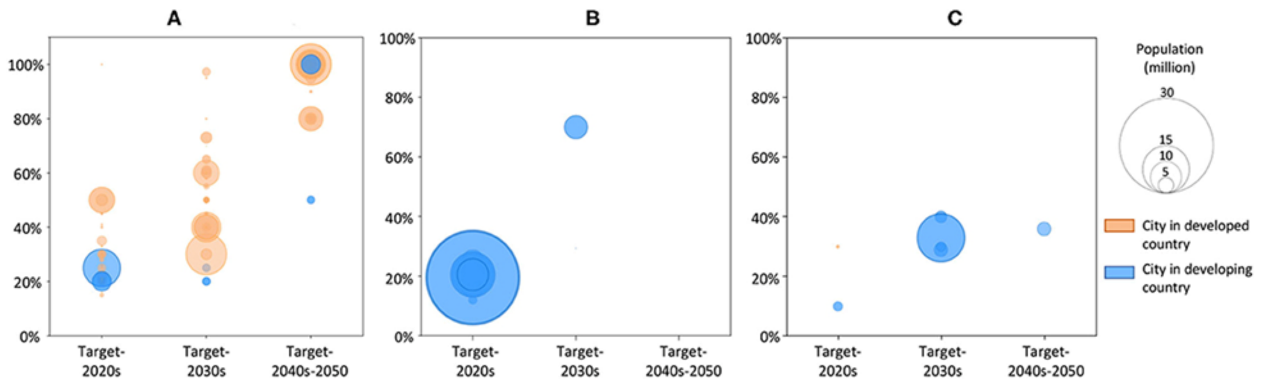


Figure 8: Annual change of per capita GHG emission in cities over 2005–2016. 1, Yokohama; 2, Paris; 3, Chennai; 4, Barcelona; 5, Milan; 6, Stockholm; 7, Los Angeles; 8, Seoul; 9, New York City; 10, Vancouver; 11, San Francisco; 12, Durban; 13, Toronto; 14, Chicago



From 2008 to 2016, the EU Emissions Trading System regulated ~50 per cent of EU GHG emissions and reduced more than one billion tons of CO_2 from 2008 to 2016 (Bayer and Aklin, 2020). Furthermore, the total GHG emissions and emissions from the power sector have been largely reduced in the USA in recent decades due to the changes from the use of coal to natural gas (Feng *et al*., 2015) and the transformation towards a cleaner and renewable energy system (Aslani and Wong, 2014; Ahn *et al*., 2021), where the climate actions have already significantly promoted GHG emission reduction. The GHG emissions continued to increase in several cities over the research period. Venice, Rio de Janeiro, Curitiba and Johannesburg were the top four cities with the largest annual increases in per capita GHG emissions, while Rio de Janeiro and Curitiba were also among the cities with the largest annual total GHG emissions. Most of them are cities in developing countries. Of the 167 analysed cities, 113 already set traceable targets for GHG emission reduction, which included absolute emission reduction targets for 68 cities, intensity targets for 40 cities, and baseline scenario targets for eight cities. Most of these cities set targets on GHG emissions (CO_2-eq), and some of them only refer to CO_2 emissions. The cities showed significant variance from 1990 to 2015, the emission targets ranged from 15 to 100 per cent reduction. Figure 9 shows the classification of these targets into near-term (2020s), mid-term (2030s), and long-term (2040s-2050) goals of emission reduction.

Figure 9: The (A) absolute emission reduction target, (B) intensity target, and (C) baseline scenario target proposed for GHGs emission mitigation in cities. (Wei et al., 2021)



In general, the Chinese Government had promised that the carbon intensity would be reduced by 40–45 per cent during the period 2005–2020. In fact, by the end of 2019, China had reduced its carbon intensity by ~48.1 per cent compared with 2005, which already exceeded its commitment. More than 30 countries have announced their carbon neutrality commitments and almost 100 countries have Net Zero-emission targets under discussion (Net Zero Tracker, 2021), which may inspire other regions to strengthen their climate goals. An increasing number of cities have also proposed carbon neutrality targets. In total, 40 (24 per cent) of the 167 cities in this study have set carbon neutrality (or Net Zero-carbon, climate neutrality) goal, which may account for more than 80 per cent of their current GHG reduction. Most European cities are striving to achieve carbon neutrality by 2050 (36 cities; i.e., 90 per cent) to synchronize with the EU's goal as a whole; four European cities even set these goals by the 2020s – 2030s. Similarly, most cities in the United States have set targets to reduce GHG emissions by 80 per cent by 2050. Copenhagen (Denmark) aims to become the first carbon-neutral capital in 2025. Studies have shown that 60 per cent of EU Covenant of Mayors' cities have been able to meet their 2020 carbon reduction targets (Hsu *et al*., 2020), which is 20 per cent of CO_2 reduction between 1990 and 2020 (Kona *et al*., 2018); however, overall, they must double their efforts to comply with the Paris Agreement of Net Zero emissions around 2050 (Salvia *et al*., 2021)" (Wei, Wu, & Chen, 2021).

The report entitled "Tallying Updated NDCs to Gauge Emissions Reductions in 2030 and Progress toward Net Zero" (2022) is a part of the energy systems modelling programme at Columbia University's Center on Global Energy Policy, which aims to assess the alignment between updated nationally determined contribution (NDCs) and current lifecycle pledges for policymakers and industry leaders to gain insight into their own national and corporate decarbonization outlooks. It presents an estimate of the percentage reduction in greenhouse gases (GHGs) from 2015 to 2030 for all commitments outlined in NDCs for countries that also have a Net Zero target.

3.2.1 US results for Net Zero targets by 2050

The latest Nationally Determined Contribution (NDC) submitted by the United States before COP26 aims for a 50–52 per cent net reduction in economy-wide greenhouse gas emissions by 2030, relative to a 2005 baseline of 6.635 $GtCO_2eq$. Achieving this objective would correspond to net economy-wide emissions of 3.185 $GtCO_2eq$ in 2030, down from 5.794 $GtCO_2eq$ in 2018 (i.e., a 45 per cent reduction from 2018 to 2030). While net GHG emissions have declined between the baseline year and 2018, the pace of reductions will need to accelerate for the United States of America to meet the objectives set forth in its NDC. Based on its NDC, the United States' emissions are estimated to decline by −4.9 per cent compound annual growth rate (CAGR) from 2018 to 2030. From 2030 to 2050, this implies that a −14.6 per cent CAGR is necessary to hit lifecycle by 2050. Over the entire period from 2018 to 2050, emissions would need to decline by −10.5 per cent CAGR.

3.2.2 EU results for Net Zero targets by 2050

The European Union has agreed to a collective binding target across the 27 member states to reduce net GHG emissions to 55 per cent below 1990 levels by 2030. The 1990 reference indicator was determined by the *National Inventory Report* published by the European Environment Agency and is subject to change based on methodological improvements; however, as of 2019, 1990 emissions for the EU is estimated at 4.27 $GtCO_2e$. Reaching the NDC target would yield net economy-wide emissions of 1.92 $GtCO_2e$ in 2030, compared to 3.33 $GtCO_2e$ in 2018 (i.e., a 42 per cent reduction from 2018 to 2030). Based on its NDC, the EU27's emissions are estimated to decline by −4.5 per cent CAGR from 2018 to 2030. From 2030 to 2050, this implies a −14.6 per cent CAGR is necessary to hit lifecycle by 2050. Over the entire period from 2018 to 2050, emissions would need to decline by −10.6 per cent CAGR.

3.2.3 Japan's results for Net Zero targets by 2050

Japan has submitted an NDC with a target of achieving a 46 per cent reduction in total greenhouse gas emissions relative to 2013 levels by 2030 (i.e., from 1.4 billion tons of carbon dioxide equivalent [$GtCO_2e$] in 2013 to 0.76 $GtCO_2e$ in 2030) in order to support its aspiration of lifecycle by 2050. In 2018, total emissions in Japan had dropped to 1.2 $GtCO_2e$ (i.e., an 18 per cent decrease compared to 2013). Based on its NDC, Japan's emissions are estimated to decline by −3.4 per cent CAGR from 2018 to 2030. From 2030 to 2050, this implies a −14.6 per cent CAGR is necessary to hit lifecycle by 2050. Over the entire period from 2018 to 2050, emissions would need to decline by −10.6 per cent CAGR.

3.2.4 China's results for Net Zero targets by 2050

China's latest NDC submitted before COP26 outlines its goals of reaching peak emissions before 2030 and achieving carbon neutrality before 2060. By 2030, China aims to achieve a 65 per cent reduction in its carbon emissions per GDP from its 2005 level of around 5.5 GtCO_2e. Achieving China's 2030 target corresponds to approximately 10 GtCO_2 in 2030. This estimate is highly sensitive to assumptions related to GDP growth in China. Since China's NDC includes only CO_2 emissions, according to the extended analysis of all greenhouse gas emissions (including methane and nitrous oxide) that was included in this report, China's GHG emissions in 2030 may reach 12.6 GtCO_2e, from 6.8 GtCO_2e in 2005. This is broadly similar to the greenhouse emissions level today at 11.7 GtCO_2e. Based on its NDC, China's emissions are estimated to grow by +0.6 per cent CAGR from 2018 to 2030. From 2030 to 2060, this implies a −11.1 per cent CAGR is necessary to hit lifecycle by 2060. Over the entire period from 2018 to 2060, emissions would need to decline by −8.7 per cent CAGR.

3.2.5 India's results for Net Zero targets by 2050

Since India's initial NDC in 2016, the country has yet to submit an updated NDC beyond a pledge made by President Modi at COP26 on 2 November 2021, which declared the following:

1. Achieve Net Zero emissions by 2070.
2. Reduce emissions intensity of GDP by 45 per cent in 2030 from 2005 levels.
3. Reduce emissions by one billion tons by 2030.
4. Generate 50 per cent of energy from renewable resources by 2030.

Thus far, the emissions intensity of India's GDP has decreased by 12 per cent between 2005 and 2010. Overall, estimates produced in this analysis show India's emissions increasing from 3.4 GtCO_2e in 2018 to 4.5 GtCO_2e in 2030 (i.e., a 32 per cent increase). Based on its NDC, India's emissions are estimated to increase by +2.5 per cent CAGR from 2018 to 2030. From 2030 to 2070, this implies a −9.0 per cent CAGR is necessary to hit life cycle by 2070. Over the entire period from 2018 to 2070, emissions would need to decline by −7.5 per cent CAGR.

This analysis revealed that the unconditional NDCs of economies with 2050 Net Zero pledges could lead to a 27 per cent reduction in GHG emissions by 2030 relative to 2015. In contrast, countries with post-2050 Net Zero pledges are projected to increase their emissions by 10 per cent between 2015 and 2030, resulting in a net global emissions reduction of 9 per cent during this period. (Glynn *et al.*, 2022).

3.3 Strategic performance assessment

According to strategic management literature, a strategy is specified with strategic targets, which in turn are specified with strategic objectives, whose establishment is measured with specific metrics.

Objectives are extremely useful because they transform strategic vision into measurable targets, enable progress/performance measurement, and oblige the organization to focus. The objectives' measurement supports the stakeholders' and employees' satisfaction, establishes the activities' clarity, and compares the conditions' evolution. Financial objectives are well-understood by an organization, but they are not enough to measure strategic progress since they depict past conditions and are mostly short-term (less than 1 year).

Indicative **financial objectives** concern:

- X % annual revenues
- X % increase of after-tax profits
- Profit margins of X %
- X % return on capital employed (ROCE)
- Cash flow to support investments

On the other hand, a strategy is a view to the future and its objectives are long term (3–5 years), and they are related to customers, internal processes, and learning and development outcomes. Indicative **strategic objectives** concern the following:

- Customer-related
- Market proportion increase (%)
- Customer retaining (%)
- New customer gaining
- Internal process related
- Failed product decrease (%)
- New product development in the next two years
- Learning and growth-related
- Increase employee training to X hours per year
- Reduce turnover to X % per year

According to the previous section's findings, carbon neutrality progress is measured according to specific targets, which can be used as the indicative **carbon neutrality objectives**:

- Achieve Net Zero emissions by a specified year (i.e., 2070)
- Reduce emissions intensity of GDP (%)
- Reduce emissions (tons)
- Generate energy from renewable resources (%)
- Organization's contribution to GHG emission reduction in the corresponding sector

The Balanced Scorecard (BSC) is a broadly used methodology that can measure the establishment of the strategic targets, via measuring objectives' performance with specific metrics (Kaplan and Norton, 1992). BSC is analysed in the following perspectives:

1 Financial perspective
2 Customer perspective
3 Internal perspective
4 Learning and growth perspective

Balanced Scorecard (BSC) is a valuable tool that can transform a strategy into a framework plan of action and secure its successful implementation. Its title is explained as follows:

- *Balanced*: Equilibrium; multidimensional perspective; integration
- *Score*: Measurement; target-orientation; long term planning; strategy
- *Card*: Systemic; simplification; registration; transparency; commitment

BSC starts with the definition of vision and strategic formulation, moves to the critical-success-factor determination, then identifies the appropriate indexes that measure performance and ends with the definition of measures and activities. Moreover, the BSC translates strategic objectives into measurable business targets, which, in turn, are forces that motivate human resources to achieve the desired outcome. BSC is a modern strategic management tool rather than a traditional controlling element. An indicative BSC for a city Carbon Neutral strategy, including some corresponding objectives, KPIs and measures that can be associated with the objectives are presented in the following (Table 3) and figure 10.

Table 3: Typical metrics for the BSC dimensions

BSC Dimension	Strategic Objectives	KPIs	Actions
Financial	Renewable energy provision to customer needs (KWh)	≥ 15%/year	Renewable Energy Production projects
	Energy use reduction (KWh/citizen)	≥ 15%/year	Measures' monitoring
Customer	Customer orientation	≤ 2% collected questionnaires	Surveys
	Public value generation for public neutrality	≤ €5 million/yr	Participation in standardization Corporate responsibility activities

BSC Dimension	Strategic Objectives	KPIs	Actions
Internal procedures	Waste disposal upgrades	≥ 50.000 Km/year reduction > 1 green points installation > 100 Km pneumatic network installation	Fleet management Green point development Pneumatic network installation
	Public transportation network's upgrades	≥ 20% routes/yr	Bus upgrades to EV
	Electromobility	≥ routes/yr	Private EV
	Building energy upgrades	≥ 1000/yr	Building energy upgrade programs
Learning and growth	Citizen attitude change activities (*Charging policies and* *Motives for device upgrades*)	> 4 motives from utilities > 10% households	> 1 motive/ utility > 10 financial support programs
	Internal Marketing	3 workshops/yr	Workshops
	Citizen attitude change activities (Charging policies and Motives for device upgrades)	> 4 motives from utilities > 10% households	> 1 motive/ utility > 10 financial support programs

Figure 10: BSC for city carbon neutrality strategic development

Financial

Strategic Objectives	Indexes	KPIs	Actions
Renewable energy provision to customer needs	KWh	≥ 15%/ year	Renewable production projects
Energy use reduction	KWh / citizen	≥ 15% reduction / year	Measures' monitoring

Customer

Strategic Objectives	Indexes	KPIs	Actions
Customer orientation	Customer Satisfaction (Scale: 1-5)	≤ 2% collected questionnaires	Surveys
Public value generation for carbon neutrality	Number of corporate responsibility activities	≤ €5 million/year	Participation in standardization activities Corporate responsibility activities

Strategic Vision

Internal Processes

Strategic Objectives	Indexes	KPIs	Actions
Waste disposal upgrades	Km/vehicle reduction Green point development Km of pneumatic networks	≥ 50.000 Km / year >1 >100 Km	Fleet management Green point development Pneumatic network installation
Public transportation networks' upgrades	Upgrade rate	≥ 20% routes/year	Electric buses
Electromobility	Compliance rate	≥ 20% routes/year	Private EV
Building energy upgrades	Number of buildings	> 1.000 / year	Building energy upgrade programs

Learn and Development

Strategic Objectives	Indexes	KPIs	Actions
Citizen training in cycling economy	Number of trainees	10% households 10% companies 30% industries	Training at schools >1000 hours Informative campaigns > 100 Business training > 10
Citizen attitude change activities	Charging policies Motives for device upgrades	>4 motives from utilities >10% households that upgrade devices	>1 motive / utility >10 financial support programs
Internal marketing	No of workshops	3 workshops / year	Workshops

The above BSC can be enhanced with an approach to a Sustainability Balanced Scorecard (SBSC) (Fathi, 2019), which would focus on the environmental perspective of the strategic formulation: the financial dimension would emphasize green ICT projects, the customer dimension would prioritise stakeholder perspectives, the internal processes would address green ICT utilization during the strategy's life cycle, and learning and development would identify the future orientation of the strategy.

4 Conclusions

This document presented alternative methods that can be applied to city carbon neutrality assessment. This document proposes and presents three different approaches for the corresponding city assessment. The first approach is based on existing standards and on previous standardization efforts for SSC development. It concerns the city carbon performance, which is measured according to the GHG produced by a city. It is calculated with the individual sector's assessment and the combination of the results. The overall performance classifies the city in a proposed carbon consumption maturity model, which associates carbon neutrality with digital transformation since it recognizes the important role that digitalization and data play for carbon neutrality. The second approach is based on findings from the literature and concerns the carbon neutrality progress assessment. This approach is performed across the globe and shows how different countries have targeted carbon neutrality by 2050. The third approach measures the strategic performance of a carbon neutrality strategy. The methodology uses the balanced scorecard to align carbon-neutral initiatives to corresponding strategic objectives and indexes.

The overall findings can be applied individually or in combination, and generate useful inputs to city leaders to evaluate and monitor their strategic implementation for local carbon neutrality. Moreover, the assessment models can generate a common understanding of how carbon neutrality can be established in cities and how digital transformation (carbon consumption maturity model) are associated.

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