SUSTAINABLE CITIES INDEX:
ENVIRONMENTAL PERFORMANCE AND CLIMATE RESILIENCE IN GLOBAL CITIES

2022

TABLE OF CONTENTS

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INTRODUCTION

An estimated 4.3 billion people, more than half the global population, live in urban areas.[1] Many of the most populous cities in the world are located near coastlines, rivers, and floodplains, exposing millions of residents to the vulnerabilities of climate change impacts.[2] Unfortunately, the poorest and most marginalized populations are disproportionately affected by climate change impacts and do not have the financial resources to mitigate risk or build resilience to increasingly frequent and severe climate disasters. The sustainable development of urban areas in planning, design, and investment in mitigation of climate change impacts is imperative to the well-being of billions of urban dwellers worldwide.

Corporate Knights has developed a quantitative, indicators-based index to assess the sustainable development of global cities. The index focuses on the environmental aspects of sustainability, but it is planned to incorporate social dimensions in future versions. The Corporate Knights Sustainable Cities Index is outcome-focused, with 11 of its 12 indicators consisting of physical measurements of air quality, access to and consumption of potable water, waste generation, automobile dependence and road density, transit and active transportation modes, open space, both local and consumption-based greenhouse gas emissions, and resilience to climate change impacts. The 12th indicator is policy-focused and covers the city's commitments to renewable energy, reduced greenhouse gas emissions, and clean transportation.

As with all Corporate Knights rating and ranking systems, the following design principles have been applied in the development of the Sustainable Cities Index:

- **Relevance:** The index and ranking are meant to be representative of sustainable cities in the current context.
- **Transparency:** The precise methodology of ranking and results of the process are fully disclosed.
- **Objectivity:** Cities are assessed using quantitative data and performance indicators.
- **Public data:** The ranking relies primarily on data points that are in the public domain and mostly accessible from free databases.
- **Comparability:** Cities are compared on the same indicators.
- **Engagement:** Cities selected for the inaugural ranking were informed prior to publication and invited to review data.
- **Stakeholders:** Stakeholder feedback is actively solicited throughout the project.

The initial publication of the index covers 50 cities (see Figure 1), including the most populous cities in each region of the world as well as several mid-sized cities with established reputations for sustainability leadership. A unique feature of the Sustainable Cities Index is an online data hub; city officials are invited to add their city to the index by registering on the hub and providing a short list of data points by visiting corporateknights.com.

(1) H. Ritchie and M. Roser (2018). "Urbanization." Retrieved from ourworldindata.org

(2) A. Kirabo Kacyira (2022). "Addressing the Sustainable Urbanization Challenge." Retrieved from un.org

Canada

- Edmonton
- Calgary
- Halifax
- Montréal
- Ottawa
- Toronto
- Vancouver

Central and South America

- Bogotá
- Curitiba
- Buenos Aires
- Medellín
- Mexico City
- Rio de Janeiro
- São Paulo

Asia and Oceania

- Canberra
- Dhaka
- Mumbai
- Singapore
- Seoul
- Sydney
- Tokyo

United States

- Chicago
- Houston
- Los Angeles
- Minneapolis
- New York City
- San Francisco
- Seattle
- Washington, D.C.

United Kingdom and Europe

- Berlin
- Copenhagen
- Helsinki
- Istanbul
- Lahti
- London
- Madrid
- Moscow
- Oslo
- Paris
- Stockholm

Africa

- Accra
- Cape Town
- Dar es Salaam
- Johannesburg
- Lagos

China

- Beijing
- Guangzhou
- Shanghai
- Shenzhen
- Tianjin

Figure 1. Map of 50 cities in the inaugural 2022 Sustainable Cities Index. Cities are grouped into 7 regions.

THE INDICATORS

It is possible to identify dozens, and even hundreds, of indicators of urban sustainability, but the Sustainable Cities Index is designed to be accessible, robust, and streamlined. The following 12 indicators were selected because data are widely available for these indicators and because they address the key dimensions of urban environmental sustainability.

Scope 1 greenhouse gas emissions per capita

Scope 1 greenhouse gas emissions occur within the city boundaries and consist primarily of the chimney, smokestack, and tailpipe emissions of greenhouse gases from fossil fuel combustion in buildings, vehicles, and industrial establishments. All else being equal, Scope 1 emissions will be higher in cities with larger buildings, bigger vehicles, and more energy-intensive industries but will be moderated in cities with high levels of energy efficiency or a high share of electricity in their energy-end-use mix; emissions from the generation of electricity are not included in the definition of Scope 1 emissions. Scope 1 emissions will also be higher in cities with significant use of coal because, compared with gas or oil, coal has a higher emission intensity and the technologies for burning coal are generally less efficient than those for burning oil or gas.

Consumption-based emissions per capita

Cities are concentrated areas of consumption of goods and services, and the greenhouse gas emissions associated with the production of those goods and services often occur outside the city boundaries, either elsewhere in the domestic economy or embedded in imports from other countries. Cities also export goods and services, and the emissions from that production, while included in the Scope 1 emissions as described above, are related to consumption that occurs outside the city. A consumption-based inventory of greenhouse gas emissions takes these factors into account by combining three categories of emissions: (1) emissions that are the direct result of final consumption in the city, primarily from residential energy use and personal transportation, (2) emissions that are "embedded" in food and other goods and services that are produced by the domestic economy and consumed in the city, and (3) emissions that are embedded in goods and services that are imported from other countries and consumed in the city. The consumption-based emissions inventory therefore represents a complete picture of the greenhouse gas emissions associated with a city's production and consumption. For additional information on our methodology for estimating consumption-based emissions, please visit corporateknights.com.

Air quality

The indicator of air quality in this index is the annual average concentration of "$PM_{2.5}$" in the city's air, which represents fine particulate matter (PM) that is equal to or less than 2.5 micrometres (µm) in diameter. When the fine particulate matter level is high, visibility is reduced and the air appears hazy. Consistent exposure to $PM_{2.5}$ pollution has profound negative impacts on human health and can cause death. It is the single biggest threat to human health, and the World Health Organization (WHO) has published air quality guidelines that limit the annual average to less than 10 µm of $PM_{2.5}$ per cubic metre of air, to reduce the burden of disease from these breathable

particles.[3] This fine particulate pollution is formed during fuel combustion and from chemical reactions in the atmosphere and can be distributed by strong winds into neighbouring cities and countries. Major sources include fuel combustion from motor vehicles, industrial processes, and wood burning or forest fires.[4]

Open public space

One of the indicators for measuring UN Sustainable Development Goal 11 of Sustainable Cities and Communities is a measure of open public space (OPS), which includes all city areas that are parks, recreation areas, greenways, and other areas accessible to the public. OPS has multifactorial benefits on inhabitants and city sustainability performance. OPS benefits inhabitants mentally and physically through recreational activity, improved social interaction, and community cohesiveness.[5] [6] In addition, OPS reduces noise, provides shade and habitats for wildlife, and reduces flooding and air pollution.[7] [8] [9] To improve performance on the OPS indicator, cities can create more high-quality OPS by planting native vegetation to reduce irrigation needs and support indigenous wildlife.

Water access

The percentage of the urban population with access to potable water is one of two indicators related to water in the Sustainable Cities Index. Access to safe water is an essential for life, whether it is used for drinking, domestic use, or food preparation. The United Nations Sustainable Development Goal target 6.1 calls for equitable and universal access to safe drinking water. Yet in 2020, two billion people did not have access to safe drinking water.

Water consumption

Universal access to safe water is tightly paired to efficient water consumption. High levels of per capita water consumption are not sustainable. As the world becomes more urbanized, there will be a significant increase in the demand on cities for safely managed drinking-water services, sanitation, and wastewater treatment.[10] The additional demand on water in urban areas can exacerbate competition for water and the depletion of aquifers and other water sources, all of

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(3) World Health Organization (2021). "WHO Global Air Quality Guidelines: Particulate Matter ($PM_{2.5}$ and PM_{10}), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide." Retrieved from apps.who.int

(4) Ontario Ministry of the Environment, Conservation and Parks (2022). "Fine Particulate Matter." Retrieved from airqualityontario.com.

(5) P.A. Sandifer, A.E. Sutton-Grier, & B.P. Ward. (2015). "Exploring Connections among Nature, Biodiversity, Ecosystem Services, and Human Health and Well-Being: Opportunities to Enhance Health and Biodiversity Conservation." *Ecosystem Services* 12, 1–15, doi: 10.1016/j.ecoser.2014.12.007.

(6) P. James, R.F. Banay, J.E. Hart, & F. Laden. (2015). "A Review of the Health Benefits of Greenness." *Curr Epidemiol Rep*. 2(2):131–142. doi: 10.1007/s40471-015-0043-7.

(7) D.E. Bowler, L. Buyung-Ali, T.M. Knight, & A.S. Pullin (2010). "Urban Greening to Cool Towns and Cities: A Systematic Review of the Empirical Evidence." *Landscape and Urban Planning*, 97(3), 147–155. doi: 10.1016/j.landurbplan.2010.05.006.

(8) Y. Depietri, F.G. Renaud, & G. Kallis. (2012). "Heat Waves and Floods in Urban Areas: A Policy-Oriented Review of Ecosystem Services. *Sustain Sci* 7, 95–107. doi: 10.1007/s11625-011-0142-4.

(9) D.J. Nowak, S. Hirabayashi, A. Bodine, & E. Greenfield (2014). "Tree and Forest Effects on Air Quality and Human Health in the United States." *Environmental Pollution*, 193, 119–129. doi: 10.1016/j.envpol.2014.05.028.

(10) World Health Organization (2022). "Drinking Water." Retrieved from who.int

which will create water security challenges.[11] It is of critical importance that inhabitants of urban areas have readily accessible safe drinking water but that they are also not over-consuming or wasting water.

Vehicle dependency

The number of registered motor vehicles per household is the first of three indicators in the index that are related to the sustainability of access and personal mobility in the city. Socioeconomic and urban structural factors play a significant role in vehicle ownership and dependency in urban areas,[12] and the density of automobiles in a city correlates with several negative environmental outcomes, including air pollution, greenhouse gas emissions, noise, risks to pedestrians and cyclists, and unproductive land use for parking and road infrastructure. The registered vehicles included in this indicator are automobiles and light trucks and do not include the scooters, motorcycles, and other two-wheeled and three-wheeled vehicles that are predominant in many middle-income countries.

Road infrastructure efficiency

Road infrastructure efficiency is defined as the road density – the length of road per square kilometre of the city's area – and is intended to reflect the efficiency with which the population is served by the roadway network. All else being equal, cities with inefficient and ultimately unsustainable transportation systems are characterized by higher road densities that go along with sprawling land use and settlement patterns. Studies have shown that a larger road capacity leads to an increase in usage of roads for personal transportation.[13]

Sustainable transport

The third transportation-related indicator in the Sustainable Cities Index captures the share of total trips made by public transit, walking, or cycling. The distinction between the number of trips and the amount of mobility (person-kilometres of travel, or "PKT") is important in this regard. Most trips are short and amenable to active transportation modes, but most PKT takes place in longer trips where automobiles predominate. This indicator considers the total number of trips made by sustainable modes, and not the PKT of their mobility. The reduction of transportation sector emissions requires changes in behaviours and substantial investment in sustainable transport modes, such as public transport, walking, and cycling. It also requires that cities be planned and built so that amenities are available to residents within walking and cycling distance, such as the "15-minute city" approach, which allows everyone in the neighbourhood to meet most of their daily needs within a short walk or bike ride of their home.

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(11) P. Romero-Lankao & D.M. Gnatz (2016). "Conceptualizing Urban Water Security in an Urbanizing World." *Current Opinion in Environmental Sustainability*, 21, 45–51, doi:10.1016/j.cosust.2016.11.002.

(12) J. Heinonen, M. Czepkiewicz, A. Árnadóttir, & J. Ottelin (2021). "Drivers of Car Ownership in a Car-Oriented City: A Mixed-Method Study." *Sustainability* 13(619), 1–26, doi: 10.3390/su13020619.

(13) J.R. Kenworthy (2020). "Passenger Transport Energy Use in Ten Swedish Cities: Understanding the Differences through a Comparative Review." *Energies* 13(14), 3719, doi: 10.3390/en13143719.

Solid waste generated

There are many possible indicators related to the generation, management, and disposal of waste in cities, and many different types of waste. Urbanization and rapid population growth is expected to result in an increase in annual waste by 70% from 2016 levels by 2050. In addition, operating effective waste management systems in urban areas is costly, comprising up to 50% of the municipal budget, but provides an essential service.[14] There is no more effective way to reduce the environmental impact of waste than to reduce its generation in the first place, and the metric of choice for the waste sector in the Sustainable Cities Index is daily solid waste generated per capita.

Climate change resilience

The poorest and most marginalized populations are disproportionately vulnerable to climate risks and do not have the financial resources to mitigate their risk of climate disasters.[15] The Notre Dame Global Adaptation Initiative (ND-GAIN) produces national indicators of vulnerability to climate change and readiness to improve resilience to climate impacts. The ND-GAIN Vulnerability score assesses the propensity for negative impacts due to climate change on food, water, health, ecosystem services, human habitat, and infrastructure. The ND-GAIN Readiness score assesses the economic, governance, and social readiness to make effective use of investments for adaptation actions.[16] The Sustainable Cities Index climate change resilience indicator is the ratio of the ND-GAIN Readiness score to the Vulnerability score, so the indicator increases with a high status of Readiness and a low status of Vulnerability to climate change impacts, in countries like Norway, and decreases with a low status of Readiness and a high status of Vulnerability, in countries like Nigeria. The ND-GAIN Technical Document provides targets and reference points for each indicator that contributes to the calculations of the national Vulnerability and Readiness scores. In the absence of a global database of urban vulnerability and readiness scores, we use the ND-GAIN national scores in the Sustainable Cities Index.

Sustainable policies

The 12th and last indicator in the Sustainable Cities Index reflects the extent to which the city has enacted policies to support renewable energy, reduced greenhouse gas emissions, and clean transportation. While all our indicator inputs are subject to review and suggested revision by the cities themselves, our starting point for this indicator is the REN21 annual Renewables in Cities Global Status Report on the status, trends, and developments of renewable energy in cities, endorsed by an advisory committee of over 20 global organizations.[17] For this report, REN21 collects data on renewable energy policies in hundreds of cities around the world. In the Sustainable Cities Index, cities are given credit for having enacted each of five key policies tracked by REN21: (1) renewable energy target, (2) electric vehicle target, (3) emission reduction target, (4) net-zero GHG target, and (5) renewable energy enabling policy.

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(14) The World Bank (2022). "Solid Waste Management." Retrieved from worldbank.org

(15) A. Kirabo Kacyira (2022). "Addressing the Sustainable Urbanization Challenge." Retrieved from un.org

(16) Notre Dame Global Adaptation Initiative (2015). "Country Index Technical Report." Retrieved from gain.nd.edu

(17) REN21 (2021). "Renewables in Cities Global Status Report." Retrieved from ren21.net

The set of indicators described above were selected for inclusion in the Corporate Knights Sustainable Cities Index because they comprise one representation of urban environmental sustainability. The inaugural index will be reviewed, and possibly revised or augmented, based on feedback from participating cities. One critical criterion for including an indicator is that data be available for cities in all parts of the world, and this resulted in some indicators being excluded. For example, the percent of energy provided by electricity in the city and other sustainability goals in urban capital and operating budgets were indicators of interest but challenged by accessibility and consistency of data.

As noted above, social dimensions of urban sustainability will be considered for future editions of the index. Social indicators such as urban poverty, employment, crime rates and public safety, homeless population, fire and emergency services, immigration rate, and civil rights and freedom are indicators for consideration. Similarly, sustainable governance indicators will be considered for future editions, including corruption, leadership gender parity, and election fairness.

Engaging with participating cities is a core design principle for the Corporate Knights Sustainable Cities Index. Feedback is encouraged on both the present indicators and for future improvements.

DATA COLLECTION

The city data for each of the 12 indicators was collected from the most credible international sources of data, including the CDP Cities,[18] C40 Knowledge Hub,[19] the International Association of Public Transport,[20] REN21,[21] the World Bank,[22] and the UN Habitat Urban Indicators Database,[23] among others. All 50 cities included in the inaugural Sustainable Cities Index were contacted to review and revise any data collected from these external databases with data from internal databases, in some cases with data that is not publicly available. The initial research to populate the index has resulted in a database of over 600 data points; the ranges of values and outliers for each of the 12 indicators are illustrated in Figure 2. City officials around the world are invited to register for the Corporate Knights Data Hub and submit 15 data points to be included in the cities universe for analysis and to receive a city sustainability scorecard.

The Sustainable Cities Index currently evaluates city boundaries as reported by cities to the CDP Open Data Portal,[24] resulting in most cities selected being core urban communities, which have different sustainability profiles than their corresponding metropolitan regions. As data availability improves, urban agglomerations will be added to the index, and representatives of metropolitan governments are encouraged to visit the Corporate Knights Data Hub and add their cities to the index to achieve this objective.[25]

(18) CDP Cities (2022). Retrieved from cdp.net

(19) C40 Knowledge Hub (2022). Retrieved from c40knowledgehub.org

(20) International Association of Public Transport (2022). Retrieved from uitp.org

(21) REN21 Renewables in Cities Global Status Report (2022). Retrieved from ren21.net

(22) The World Bank Data Indicators (2022). Retrieved from data.worldbank.org

(23) The UN Habitat Urban Indicators Database (2022). Retrieved from data.unhabitat.org

(24) CDP Open Data Portal (2022). Retrieved from data.cdp.net

(25) Corporate Knights Data Hub (2022). Retrieved from data.corporateknights.com

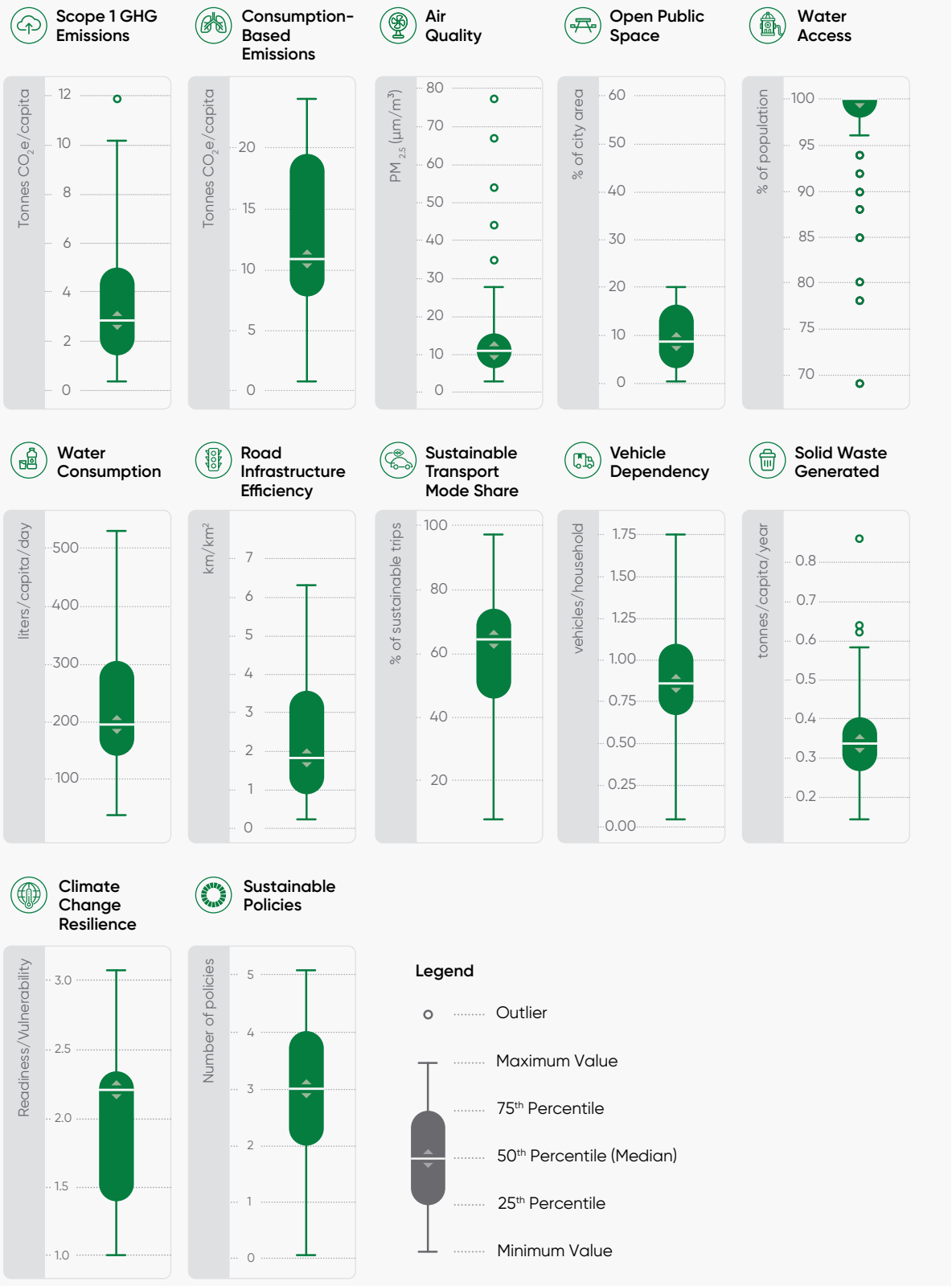

Figure 2. The distribution of data obtained for each indicator for the 50 cities in the initial release of the Sustainable Cities database.

SUSTAINABLE CITIES INDEX RESULTS

Percentile ranking was applied to indicator data to score each city based on the relative best practice for that indicator. Further, letter grades were assigned to scores for easy comparison between indicators and cities. The method for converting the indicator data points to scores and letter grades, and for weighting the different indicators to generate the overall letter grade for each city, is described in detail in a companion report available on the Corporate Knights website. The overall rankings are illustrated in Figure 3 in relation to city populations, and Tables A and B contains a complete set of results for each city and each indicator.

Figure 3. Sustainable Cities Index Rank vs. Population.

Overall ranking

The highest-scoring city on the 2022 Sustainable Cities Index ranking is Stockholm, followed by Oslo, Copenhagen, Lahti, and London (Tables A and B). Seven of the top 10 cities are in the United Kingdom and Europe, attributable to sustainability leadership in countries in the European Union. Tokyo ranked seventh overall, and first among cities in Asia and Oceania. Vancouver and Toronto ranked eighth and ninth, respectively, and in general Canadian cities are the highest-scoring North American cities in the index. The highest-scoring city in Africa was Cape Town, South Africa, ranking 12th overall, followed by Accra, Ghana, ranking 15th. The best-performing cities in Central and South America were the Brazilian cities of Curitiba, ranking 14th, and Rio de Janeiro, at 23rd. The best-performing cities in the United States were San Francisco and New York City, ranking 16th and 19th, respectively. Of the Chinese cities included in the index, Beijing, in the 30th slot, ranked highest.

As illustrated in Figure 3, cities with smaller populations generally score higher than more populous cities in the index, and some of the most populous cities are among the lowest-ranking, including Istanbul in Turkey, Lagos in Nigeria, and Shanghai in China (Tables A and B). However, London (population eight million) and Tokyo (population 13 million) rank in the top 10, illustrating that megacities can achieve high sustainability performance. London and Tokyo both scored well in indicators such as air quality, sustainable transport modes, water access, and renewable energy policy.

Table A. 2022 Corporate Knights Sustainable Cities Index results of six of twelve indicators.

Rank	City	Country	Population	Scope 1 GHG Emissions	Consumption-Based GHG Emissions	Air quality	Open Public Space	Water Access	Water Consumption	Overall Grade
1	Stockholm	Sweden	981,105	A	C	A+	A+	A+	B	A+
2	Oslo	Norway	697,010	B	C	A+	B	A+	B	A
3	Copenhagen	Denmark	638,147	A	C	A+	A	A+	A	A
4	Lahti	Finland	120,133	C	C	A+	B	A+	A	A
5	London	United Kingdom	8,908,081	C	C	A+	A+	A+	B	A
6	Helsinki	Finland	656,920	C	C	A+	A+	A+	B	A
7	Tokyo	Japan	13,957,977	B	C	A+	C	B	C	A
8	Vancouver	Canada	654,000	C	C	A+	C	A+	D	A
9	Toronto	Canada	2,956,024	C	C	A+	B	A+	C	B
10	Berlin	Germany	3,769,000	C	C	B	C	A+	A	B
11	Ottawa	Canada	1,006,211	C	C	A+	C	A+	C	B
12	Cape Town	South Africa	4,423,834	B	C	A+	B	D	B	B
13	Madrid	Spain	3,223,334	B	C	A+	C	A+	C	B
14	Curitiba	Brazil	1,948,626	B	B	A+	C	A+	B	B
15	Accra	Ghana	2,514,005	A	A+	F	D	F	A	B
16	San Francisco	United States	881,549	C	C	A+	B	A+	B	B
17	Paris	France	2,210,875	B	C	D	C	A+	B	B
18	Halifax	Canada	421,939	C	C	A+	C	A+	D	B
19	New York City	United States	8,399,000	C	C	A+	C	A+	D	B
20	Montréal	Canada	2,069,849	C	C	A+	C	A+	B	B
21	Edmonton	Canada	1,047,526	C	C	A+	C	A+	B	B
22	Calgary	Canada	1,306,784	C	C	A+	B	A+	D	B
23	Rio de Janeiro	Brazil	6,747,815	B	B	A+	C	F	C	B
24	Washington	United States	708,253	C	C	A+	B	A+	B	B
25	Seoul	South Korea	9,911,088	C	C	D	A	A+	C	B
26	Sydney	Australia	248,736	C	C	A	C	B	C	B
27	Medellín	Colombia	2,533,424	A	B	D	C	B	C	C
28	Moscow	Russia	12,655,050	B	C	B	C	A+	C	C
29	Los Angeles	United States	4,021,488	C	C	D	A	A+	C	C
30	Beijing	China	18,590,000	C	C	B	C	B	D	C
31	Mexico City	Mexico	9,041,395	C	B	D	A+	B	C	C
32	Seattle	United States	744,955	C	C	A+	C	A+	C	C
33	Dhaka	Bangladesh	12,000,000	A+	A	F	D	F	B	C
34	Shenzhen	China	11,908,000	C	C	D	A+	C	B	C
35	Buenos Aires	Argentina	3,068,043	C	C	D	C	B	D	C
36	Bogotá	Colombia	7,333,415	B	B	D	C	B	B	C
37	Canberra	Australia	420,960	C	C	D	B	A+	C	C
38	Minneapolis	United States	429,606	C	C	B	C	A+	C	C
39	Houston	United States	2,320,268	C	C	A	C	A+	C	C
40	Lagos	Nigeria	21,000,000	A	A	F	D	D	A+	C
41	Chicago	United States	2,693,976	C	C	B	C	A+	C	C
42	São Paulo	Brazil	12,038,000	A	B	D	C	C	B	C
43	Dar es Salaam	Tanzania	6,041,000	D	A+	F	D	D	B	C
44	Mumbai	India	12,828,821	A	A	F	C	C	A	C
45	Singapore	Singapore	5,685,807	C	C	D	C	A+	B	D
46	Istanbul	Turkey	15,462,452	B	B	D	C	A+	C	D
47	Johannesburg	South Africa	5,870,000	B	C	F	B	B	C	D
48	Guangzhou	China	15,305,900	C	C	F	B	B	D	D
49	Shanghai	China	24,153,000	C	C	F	B	B	D	F
50	Tianjin	China	12,784,000	C	C	F	D	B	A	F

The next six of twelve indicators see on the next page

Table B. 2022 Corporate Knights Sustainable Cities Index results of six of twelve indicators.

Rank	City	Country	Population	Road Infrastructure Efficiency	Sustainable Transport	Vehicle Dependency	Solid Waste Generated	Climate Change Resilience	Sustainable Policies	Overall Grade
1	Stockholm	Sweden	981,105	C	C	A	C	A	A	A+
2	Oslo	Norway	697,010	A	B	C	C	A+	A	A
3	Copenhagen	Denmark	638,147	A	B	C	C	A	B	A
4	Lahti	Finland	120,133	A+	C	C	B	A	A	A
5	London	United Kingdom	8,908,081	C	B	C	C	A	A+	A
6	Helsinki	Finland	656,920	B	A	C	B	A	B	A
7	Tokyo	Japan	13,957,977	B	B	B	A	A	A	A
8	Vancouver	Canada	654,000	C	C	C	A	A	A+	A
9	Toronto	Canada	2,956,024	C	C	C	B	A	A+	B
10	Berlin	Germany	3,769,000	C	B	C	D	A	A+	B
11	Ottawa	Canada	1,006,211	C	C	C	A	A	A	B
12	Cape Town	South Africa	4,423,834	C	C	C	B	D	A	B
13	Madrid	Spain	3,223,334	C	B	B	C	B	B	B
14	Curitiba	Brazil	1,948,626	B	C	C	C	D	A	B
15	Accra	Ghana	2,514,005	B	A	C	B	D	C	B
16	San Francisco	United States	881,549	C	C	C	C	B	A	B
17	Paris	France	2,210,875	C	A+	C	C	A	A	B
18	Halifax	Canada	421,939	B	D	C	A	A	B	B
19	New York City	United States	8,399,000	C	B	C	C	B	A	B
20	Montréal	Canada	2,069,849	C	C	C	C	A	B	B
21	Edmonton	Canada	1,047,526	C	D	C	B	A	A	B
22	Calgary	Canada	1,306,784	C	D	C	D	A	A+	B
23	Rio de Janeiro	Brazil	6,747,815	C	B	C	B	D	B	B
24	Washington	United States	708,253	C	C	C	D	B	B	B
25	Seoul	South Korea	9,911,088	C	B	C	B	A	A+	B
26	Sydney	Australia	248,736	C	C	C	B	A	C	B
27	Medellín	Colombia	2,533,424	C	B	B	C	D	B	C
28	Moscow	Russia	12,655,050	C	B	C	D	C	B	C
29	Los Angeles	United States	4,021,488	C	D	C	C	B	A	C
30	Beijing	China	18,590,000	A	B	C	C	C	B	C
31	Mexico City	Mexico	9,041,395	C	C	C	B	D	A	C
32	Seattle	United States	744,955	C	C	C	C	B	C	C
33	Dhaka	Bangladesh	12,000,000	C	B	A+	A+	D	D	C
34	Shenzhen	China	11,908,000	B	B	C	D	C	B	C
35	Buenos Aires	Argentina	3,068,043	C	B	C	D	D	A+	C
36	Bogotá	Colombia	7,333,415	C	B	C	C	D	D	C
37	Canberra	Australia	420,960	C	D	C	D	A	A+	C
38	Minneapolis	United States	429,606	C	D	C	B	B	C	C
39	Houston	United States	2,320,268	C	F	C	C	B	B	C
40	Lagos	Nigeria	21,000,000	B	A+	C	A	D	D	C
41	Chicago	United States	2,693,976	C	D	C	C	B	B	C
42	São Paulo	Brazil	12,038,000	C	B	C	C	D	C	C
43	Dar es Salaam	Tanzania	6,041,000	B	A	C	A	D	D	C
44	Mumbai	India	12,828,821	C	B	C	A	D	F	C
45	Singapore	Singapore	5,685,807	C	B	B	D	A	C	D
46	Istanbul	Turkey	15,462,452	A	B	C	C	C	C	D
47	Johannesburg	South Africa	5,870,000	C	C	C	B	D	C	D
48	Guangzhou	China	15,305,900	A	A+	C	B	C	D	D
49	Shanghai	China	24,153,000	B	B	B	D	C	D	F
50	Tianjin	China	12,784,000	B	B	B	C	C	D	F

Cities in high-income countries are more likely to rank higher in the index than cities in middle-income countries, but there are cities in high-income countries with very low sustainability scores (e.g., Houston and Chicago in the United States), and there are cities in middle-income countries with relatively high sustainability scores (e.g., Accra and Curitiba in Ghana and Brazil). It may be surprising that Accra would rank higher than San Francisco and other cities in North America or Europe, but the weights assigned to per capita greenhouse gas emissions and to automobile dependence disadvantage sprawling cities with high levels of consumption and energy use. While the majority (58%) of cities included in the 2022 Sustainable Cities Index are in high-income countries and the remaining cities (42%) are in middle-income countries, most (80%) of the 25 top-performing cities on the index are in high-income countries, and the bottom 25 are disproportionately represented (68%) by cities in middle-income countries. These income disparities in sustainability performance are also evident through the climate change resilience indicator. Ranking scores for this indicator arranges cities into the income status of their countries: cities with low vulnerability and high readiness are in high-income countries, and cities with high vulnerability and low readiness are in middle-income countries. This trend reveals a key message: the effects of climate change disproportionately impact the world's most vulnerable people. Climate change will exacerbate existing issues, including reducing access to safe drinking water, forcing migration due to land loss in coastal regions, posing a severe risk for food security, and negatively affecting human health.[26] It is imperative to reduce global poverty while concurrently strengthening the capacity of those living in poverty to adapt to climate change.

Indicator rankings

The 50 cities in the index are scored out of 1.0 relative to the best sustainability outcome for each indicator. The scores of each indicator are illustrated in Figure 4 and Figure 5, plotted against national per capita GDP of the countries in which the cities are located.

GREENHOUSE GAS EMISSIONS

For both Scope 1 GHG emissions per capita and consumption-based emissions per capita, the cities in high-income countries score poorly, reflecting high levels of direct emissions (large homes, large vehicles) and high levels of consumption-based emissions that have historically been associated with high levels of income. For example, Dhaka in Bangladesh has 0.5 tonnes CO_2e per capita Scope 1 GHG emissions, and among the lowest-scoring cities was Houston, with 8.5 tonnes CO_2e per capita. Among the highest-scoring cities for consumption-based GHG emissions per capita were Medellín and São Paulo in South America (4 and 5 tonnes CO_2e per capita, respectively), and among cities scoring the lowest was Canberra, Australia, with 22 tonnes CO_2e per capita. Along with the climate change resilience indicator, the consumption-based GHG emissions per capita indicator exhibits the clearest correlation with per capita GDP, reflecting the tendency for the high-income countries to be emissions importers and the middle-income countries to be emissions exporters.

The average distribution of sources of consumption-based GHG emissions for the cities in the index is illustrated in Figure 6, a pattern that is similar to those found in other analyses of consumption-based emissions in cities.[27] Roughly half of urban consumption-based GHG emissions in cities originate in the nation's domestic economy (including in the city itself), with the remainder split between emissions embodied in goods imported from other countries, and emissions resulting from the fuel and electricity use and waste generation of households and personal transportation within the city.

(26) OECD (2002). "Poverty and Climate Change." Retrieved from oecd.org

(27) C40 (2018). "Consumption-Based GHG Emissions of C40 Cities." Retrieved from c40knowledgehub.org

Figure 4. Distribution of indicator scores vs. GDP per capita.

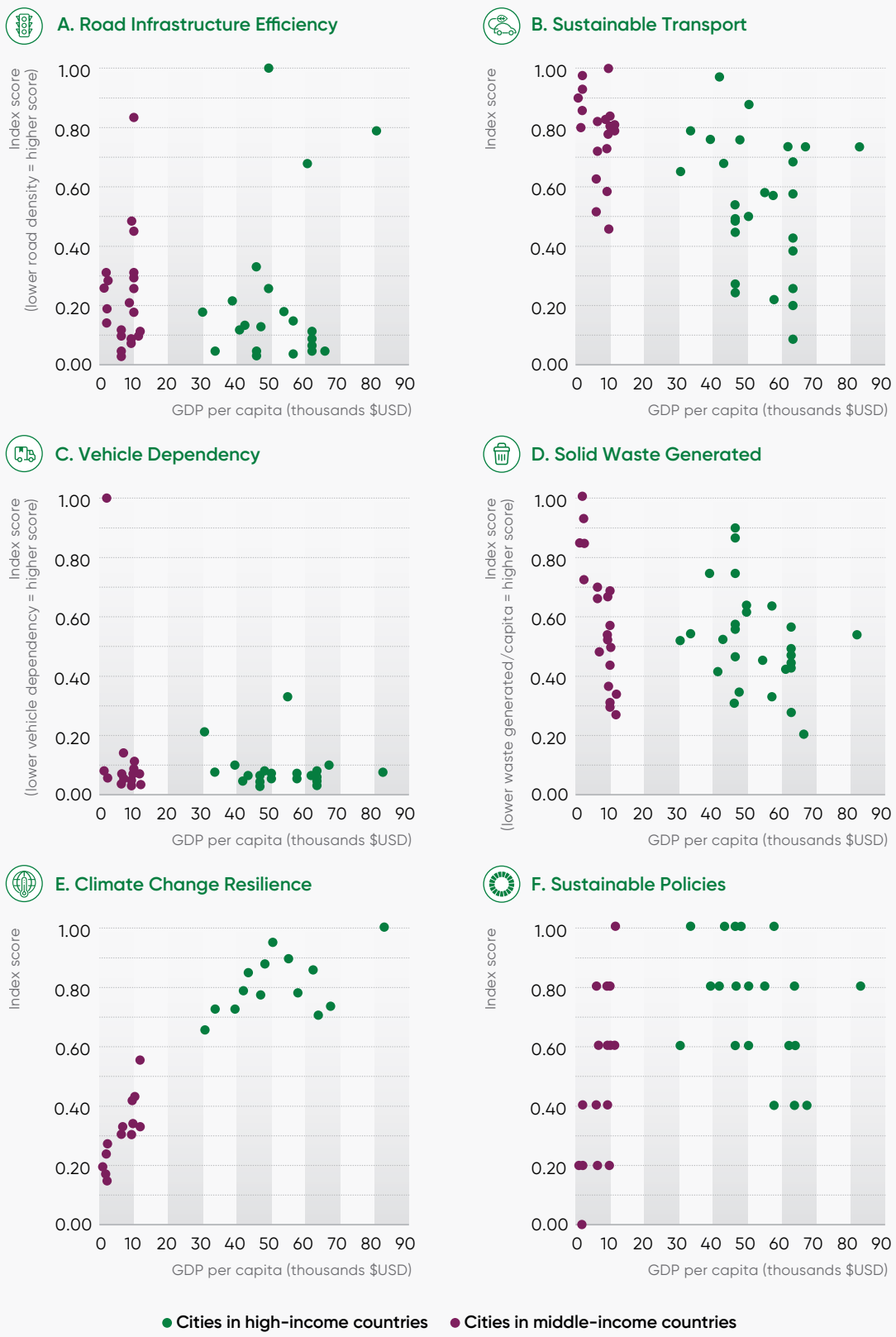

Figure 5. Distribution of indicator scores vs. GDP per capita.

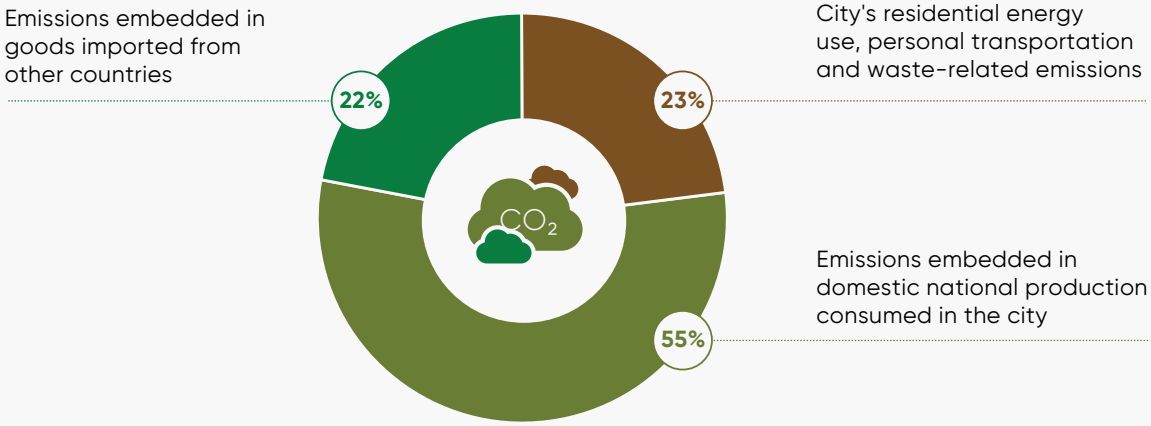

Figure 6. Origin of consumption-based emissions (for more details, see full methodology).

AIR QUALITY

The World Health Organization guideline of less than 10 µm/m³ is adopted as the benchmark in the Corporate Knights Sustainable Cities Index.[28] The only region with a consistently acceptable indicator of air quality is Canada. Cities in Asia and Oceania, especially Dhaka, Bangladesh, and cities in China have the poorest air quality, which causes negative health effects on their inhabitants. In addition to its use in power generation, coal burned directly for cooking, heating, and industrial applications is a significant contributor to urban air pollution, as is wood and biomass combustion. Diesel engines are another significant source of small particle pollution. Reducing the use of or mitigating the emissions from coal, diesel, and biomass combustion is one of the most effective measures for improving urban air quality. Forest fires are an additional contributor to negative air quality, and often a result of climate change, and have resulted in lower air qualities in cities like Canberra, Australia.[29]

OPEN PUBLIC SPACE

To achieve UN Sustainable Development Goal 11 of Sustainable Cities and Communities, a minimum of 45% of city area to be considered open public space (OPS) is recommended.[30] Very few cities in the index have OPS near this target, but Mexico City (59%), Stockholm (48%), Shenzhen (41%), London (39%), and Helsinki (34%) scored the highest. Increasing their percentage of OPS is an opportunity for improvement for many cities.

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(28) World Health Organization (2021). "WHO Global Air Quality Guidelines: Particulate Matter ($PM_{2.5}$ and PM_{10}), Ozone, Nitrogen Dioxide, Sulfur Dioxide and Carbon Monoxide." Retrieved from apps.who.int

(29) In 2019, wildfires resulted in high levels of $PM_{2.5}$ pollution over Canberra, and this had a negative effect on the city's air quality score.

(30) Deloitte (2021). "Green Planning of Public Spaces." Retrieved from deloitte.com

TRANSPORTATION AND MOBILITY ACCESS

American cities like Los Angeles and Houston are heavily dependent on vehicles and road infrastructure for personal transportation, with low trips by sustainable transport modes such as walking, cycling, or public transit. The opposite is true of many cities in the Global South, including Singapore and Bogotá, whose residents have lower vehicle dependency and take more trips using sustainable modes of transport.

The three transportation indicators included in the index (road infrastructure efficiency, sustainable transport, vehicle dependency) together provide powerful insight into the extent to which urban form, transportation infrastructure, and residents' motivations and behaviour contribute to the overall sustainability performance of the city. North American cities are the worst-performing cities in the index on these three transportation indicators. Ten cities across Africa, China, Asia and Oceania, Europe, and Central and South America have a sustainable transport mode share of 75% or greater, comparable to the City of Copenhagen's target percentage of trips by foot, bicycle, or public transport.[31]

Regarding vehicle dependency, North American and some Central and South American cities are highly dependent on personal vehicles for transportation, with more than one vehicle per household. However, over the entire group in the index, more than 65% of cities have less than one vehicle per household, and 14% of cities have 0.5 vehicles per household or less, which would be ideal. Leadership for this indicator is demonstrated by cities like Madrid and Singapore, which have less than 0.5 vehicles per household.

Road infrastructure efficiency, measured as road density, is an indicator of sustainable development and design of the city for road transportation. Once again, cities in Canada and the United States have the highest road density, whereas all cities in China and five cities in Europe (Lahti, Oslo, Copenhagen, Istanbul, and Helsinki) have highly efficient road infrastructure, with road densities less than 1 km/km^2.

WATER AND WASTE

Indicators for water consumption and potable water access reveal that in North American cities, the average consumption of water is 256 litres of water consumed per capita per day. Water consumption in cities in China was the highest, at 342 litres of water per capita per day, while water consumption of cities in the Global North was lowest in Europe and the United Kingdom, with 123 litres of water per capita per day. Some cities in high-income countries – Copenhagen, Berlin, and Lahti – have been very successful in reducing per capita water consumption to less than 120 litres per day. In contrast, several cities in Africa are consuming less than 100 litres of water per capita, which often indicates water shortages or challenges in water supply; indeed, many residents of these African cities do not have access to potable water. The city of Dhaka has the lowest percentage of population with access to potable drinking water, at only 69%. As a result, 3,720,000 million people living in Dhaka lack access to safe water sources, critically impacting the health and safety of inhabitants.

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(31) Copenhagen Urban Development (2022). "Mobility – How We Get Around in the City." Retrieved from urbandevelopmentcph.kk.dk.

Solid waste generated varies over a wide range of cities in the index, and examples of both low and high levels of per capita solid waste generation can be found across a range of per capita GDP levels. Solid waste generation is largely influenced by the local municipal management of waste, including recycling and composting programs. High-performing cities include Vancouver, Ottawa, and Halifax, with less than 250 kg of waste generated per capita per year. Cities that produce high amounts of solid waste per capita per year include Washington, D.C., and Singapore at 600 kg generated per capita per year.

CLIMATE CHANGE RESILIENCE

Climate change resilience is an indicator of national Notre Dame Global Adaptation Initiative Readiness and Vulnerability scores, where the highest score was for Oslo, Norway. A very high score indicates that the country has low vulnerability to climate change impacts and is highly adaptable in the case that climate change disasters affect inhabitants. It is no surprise that the lowest-scoring cities are in countries in Africa, Central and South America, and Asia and Oceania, which are both geographically vulnerable to severe climate disasters and often face economic challenges in adapting to and coping with climate disasters when they do occur.

SUSTAINABLE POLICIES

To achieve the transition to being fossil-fuel-free, many cities around the world, like Vancouver, Sydney, and San Francisco, have adopted 100% renewable energy targets. This ambitious goal requires supporting policy and targets to achieve stepwise progress toward 100% renewable-energy-powered cities with net-zero GHG emissions and electric vehicles. Few cities have enacted all five of the REN21 policies for (1) renewable energy target, (2) electric vehicle target, (3) emission reduction target, (4) net-zero GHG target, and (5) renewable-energy-enabling policy. City leadership on this indicator includes Vancouver, Toronto, Seoul, London, Berlin, Buenos Aires, Canberra, and Calgary.

TARGETS FOR CITY SUSTAINABILITY PERFORMANCE

The Corporate Knights Sustainable Cities Index ranks cities based on their performance relative to other cities in the index. Through the index, we were able to collect a globally representative sample of city sustainability data, which enabled us to identify urban sustainability performance targets. In Table C, we identified targets for what would constitute exemplary performance for each of the 12 indicators. The targets were determined with reference to the best-performing cities on each indicator in the index and based on the literature as being consistent with a sustainable economy. The targets will be recalibrated annually based on improved performance of cities and developments in the literature.

In the case of indicators of greenhouse gas emissions, the target is set to zero, reflecting the need to eliminate greenhouse gas emissions to avoid catastrophic climate change impacts. Stockholm has the lowest Scope 1 GHG emissions per capita, at 0.83 tonnes CO_2e, but its total GHG footprint, as represented by its consumption-based emissions, is 9 tonnes CO_2e per capita. Consumption-based emissions are the best indicator of per capita GHG emissions and the best basis for comparison between cities. Of the 50 cities in the index, consumption-based inventories had an average of 12 tonnes CO_2e per capita, with cities in high-income countries averaging 17 tonnes CO_2e per capita and cities in middle-income countries averaging 6 tonnes CO_2e per capita. There is clearly a significant gap between even the highest-scoring cities on the index and the ultimate objective of zero emissions.

Table C. Ideal benchmark values for indicators in Sustainable Cities Index.

Sustainable Cities Index Indicator	Target	Units
Scope 1 GHG Emissions	Net-Zero	tonnes CO_2e/capita
Consumption-Based Emissions	Net-Zero	tonnes CO_2e/capita
Air Quality ($PM_{2.5}$)	< 10	µg/m^3
Open Public Space	45	%
Water Access	100	%
Water Consumption	100-150	litres/capita/day
Road Infrastructure Efficiency	< 1	km/km^2
Sustainable Transport Mode Share	75	%
Vehicle Dependency	< 1	vehicles/household
Solid Waste Generated	< 0.3	tonnes/capita/year
Climate Change Resilience	> 3	ratio
Sustainable Policies	5	/5

CONCLUSION

The 2022 Sustainable Cities Index highlights that the perfect city does not exist; among the 50 cities included, no single city received the highest score on each of the 12 indicators. Instead, the index reveals incidences of exemplary performance among mid-sized cities and megacities, in the Global North and Global South, in middle-income and high-income countries. Therefore, all cities, irrespective of size or location, that are keen to improve their sustainability performance can look toward city leaders on specific indicators and examine the policies and practices that dictate their success.

It is our goal that the annual trend analysis of city sustainability drives tangible and meaningful outcomes in cities that improve the quality of life of inhabitants and reduce the impacts of climate change.