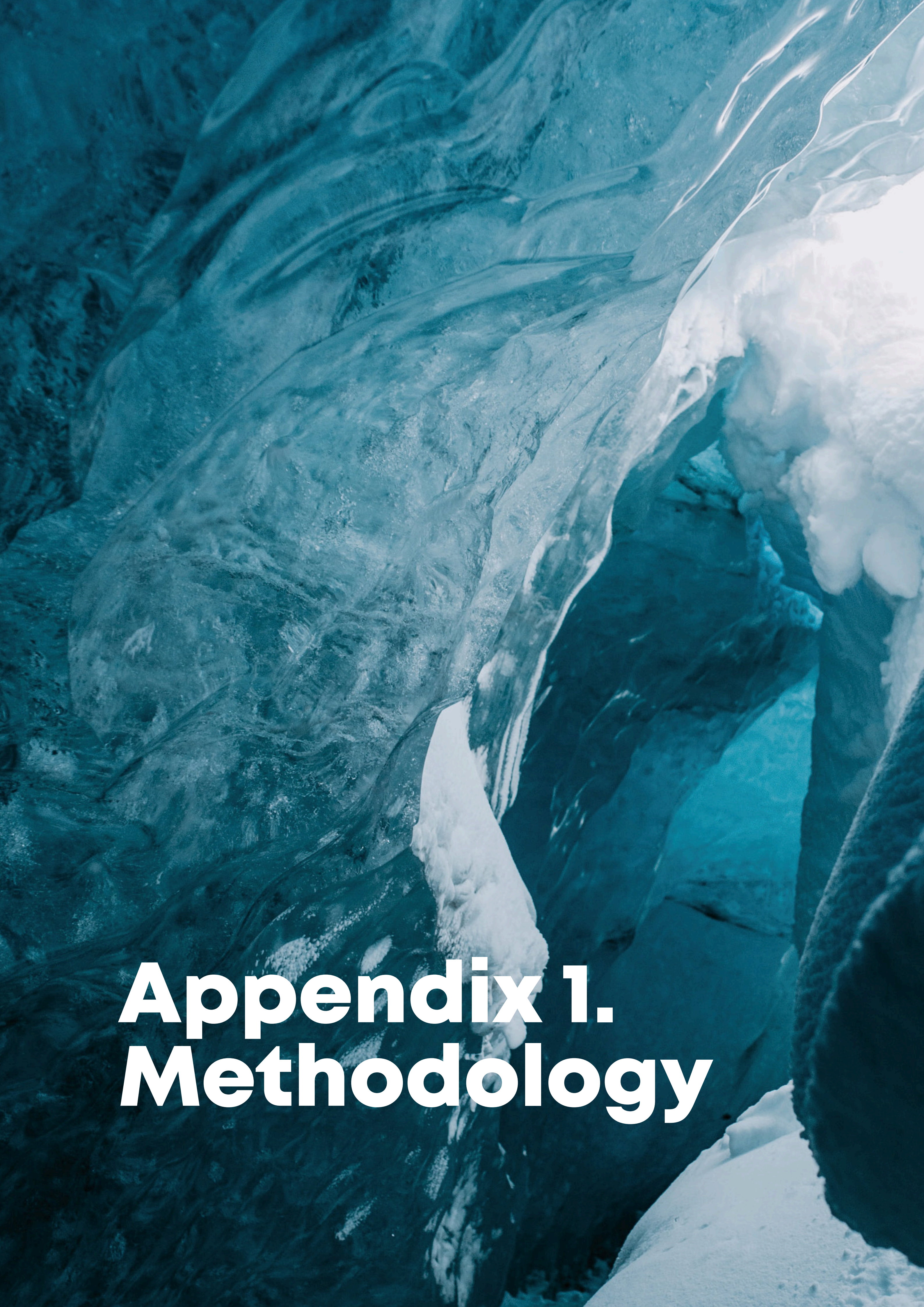


Appendix 1. Methodology

General Approach

1. Compare cities and award points in each category

The score of a city in each category can take a value from 10 to 100 points and is calculated using quantitative (basic) and qualitative (adjustment) indicators.

Quantitative indicators are based on statistical data in the categories, while **qualitative** indicators are based on targets set by city governments as defined in and made public through their climate policies or other official documents.

Cities are compared according to the following algorithm:

- Based on the value of the quantitative indicator(s), the city is assigned an **initial score** ranging from 10 to 100, where 100 is the best score and 10 is the worst score (if 2 quantitative indicators are used, the city is assigned an initial score in the range from 5 to 50 for each indicator, where 50 points is the best score and 5 points is the worst).
- For cities whose initial score is less than ¾ of the maximum (i.e., the city did not perform particularly well in a given category), an adjustment factor is applied: if the city government does not have any specific plans to improve such performance (qualitative indicator), the initial score is reduced by 10%, thereby giving the ranking a dimension of potential future improvements rather than just stating the status quo.

2. Calculate the final score

The final score is calculated as a weighted average of the scores assigned to the cities in each category.

For calculation purposes, each of the categories is assigned an individual weight representing the category's relative contribution to urban greenhouse gas emissions (for more details, see the Assignment of Weights section).

The resulting final score is normalized to a value between 10 and 100.

Energy Sources

Basic indicator: electricity consumption by generation sources (coal, oil and petroleum products, natural gas, nuclear, other nonrenewable energy sources, RESs), GWh

Period: 2019–2021, depending on data availability

Note: 17 out of 20 cities in the ranking provided data to the CDP database in 2022, and that information was used in the research. Three out of these 17 cities provide national-level energy mix.

For the 3 cities that did not provide data to the CDP, national level data of the International Energy Agency was used.

Adjustment factor: targets to raise the share of RESs

Methodology to calculate the initial score:

1. Each energy source is assigned a weight to capture information on the level of greenhouse gas emissions from that source. The weights for coal, oil, and gas are calculated as the ratio of emissions from the combustion of a corresponding type of fuel [50] to the volume of its combustion [51]. The generation of nuclear energy and energy from RESs does not have greenhouse gas emissions [52,53], so a zero factor is applied to these energy sources.

2. The amounts of energy consumed from each energy source in the city are multiplied by the weights described in step 1 and summed up for each city.

3. Each city is assigned from 10 points to 100 points in proportion to the value obtained in step 2 (where 10 points are assigned to the city with the highest value of the indicator and 100 points to the one with the lowest value).

Energy Consumption

Basic indicator: electricity and thermal energy consumption per capita per year, kWh, adjusted for the average annual temperature.

Note: Due to data availability limitations, the research focuses on electricity and heat consumption, which comprises only part of total energy consumption of a city.

There are other ways energy resources like coal, oil, and gas can be used inside the city to produce energy.

For example, the energy released from burning fossil fuels can be used not only to generate electricity, but also to operate industrial equipment (for example, smelters), while petroleum products are most commonly used to fuel internal combustion engines in motor vehicles, rather than to generate electricity and heat [54].

Period: 2019–2021, depending on data availability

Note: During the preparation for the research, the latest available data on electricity consumption by the ranked cities were collected: for 11 cities, the last available year was 2021; for 3 cities, 2020; and for 6 cities, 2019.

2020 was the year of the COVID-19 pandemic [55], when many countries imposed restrictive measures and lockdowns and partially suspended production, etc. [56]. We analyzed the impact of COVID-19 on electricity consumption in the world and in the ranked cities to determine the possibility of making a fair comparison between cities with the most up-to-date data in 2020 and cities with the most up-to-date data in other years.

According to the International Energy Agency, in 2020, global electricity consumption decreased by 1% compared to 2019 [57].

Data on electricity consumption dynamics in 2020 relative to 2019 available for the ranked cities showed a slight drop in electricity consumption (about 4% on average) in most cities and a slight increase (4%) in one of them.

The analysis did not produce conclusive evidence that the COVID-19 pandemic made a significant impact on electricity consumption, so, for the purposes of the research, the latest available data for any particular city were used without any adjustments.

Adjustment factor: targets to reduce energy consumption

Methodology to calculate the initial score:

1. Per capita electricity consumption is calculated as follows: the electricity consumption data by the city in the latest available year is divided by the city's population in the same year.

2. The thermal energy consumption is calculated: since in most cases the data on thermal energy consumption are available at the national level only (data from the International Energy Agency [58]), an additional calculation is made to measure thermal energy consumption

specific to a particular city. In cities where a central heating system is used, the value of thermal energy consumption at the national level is multiplied by a ratio of thermal energy consumption at city level to national level (such ratio is obtained when both city and national level data are available) and added to the indicator obtained in step 1.

3. To make sure comparable values are used for each city, the data from step 2 are adjusted for the average annual temperature: the actual consumption of electricity and thermal energy is divided by an "optimal energy consumption factor" (based on an equation showing the relationship between energy consumption and average annual temperatures in high- and middle-income countries according to the International Energy Agency [58]). The resulting value shows the city's energy efficiency adjusted for climate.

4. Each city is assigned from 10 points to 100 points in proportion to the value obtained in step 3 (where 10 points are assigned to the city with the highest value of the indicator and 100 points to the one with the lowest value).

Transport

Basic indicator: types of transport used by the residents on a daily basis, by type (metro, tram, bus, car, bicycle, pedestrians), %

Period: as of March 2023

Adjustment factor: targets to increase the share of clean transport

Methodology to calculate the initial score:

1. For each city, the proportion of the residents using clean transport or human-powered mobility for daily commute is calculated. For calculation purposes, clean transport includes metro, tram, bicycle, walking, and (partly) buses and private cars.

To account for clean buses, the share of the population using buses is multiplied by the share of clean buses in the city.

To account for private cars, the share of the population using private cars is multiplied by the share of private electric cars in the country.

Note: National level data are used to calculate the share of clean private cars due to the lack of relevant data at the city level.

2. Each city is assigned from 10 points to 100 points in proportion to the value obtained in step 1 (where 10 points are assigned to the city with the lowest value of the indicator and 100 points to the one with the highest value).

Green Spaces

Basic indicator: the ratio of green space area to the total area of the city, %

Period: as of March 2023

Adjustment factor: targets to expand/ prevent the reduction of area of green spaces

Methodology to calculate the initial score:

1. The area of green spaces in the city is determined based on online map data (Google Maps).

2. The ratio of green space area to the total area of the city is calculated: the value obtained in step 1 is divided by the value of the city area.

3. Each city is assigned from 10 points to 100 points in proportion to the value obtained in step 2 (where 10 points are assigned to the city with the lowest value of the indicator and 100 points to the one with the highest value).

Waste

Basic indicator 1: waste generation: mass of municipal solid waste (MSW) generated by businesses and households, kg per capita

Period: 2020–2021, depending on data availability

Basic indicator 2: waste management: mass of municipal solid waste generated by businesses and households disposed of in landfill, kg per capita

Period: 2020–2021, depending on data availability

Adjustment factor: targets to reduce the mass of generated waste or to reduce the proportion or volume of waste that ends up in landfills

Methodology to calculate the initial score:

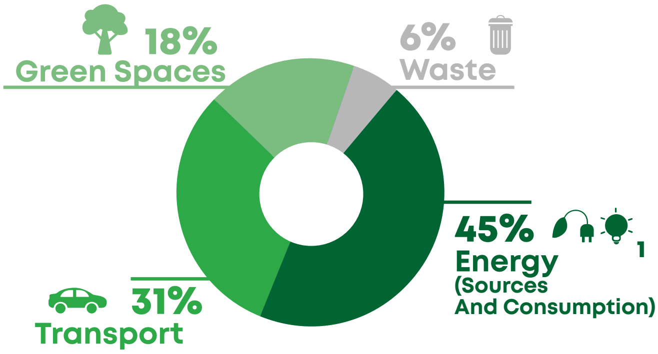
1. Per capita data on the mass of MSW and the mass of MSW disposed of in landfills are calculated: the data on the mass of MSW and the mass of MSW disposed in landfills for the latest available year are divided by the data on the population of the city in the same year.

2. Each city is assigned from 5 to 50 points in proportion to the value of each of the basic indicators (where 5 points are assigned to the city with the highest value of the indicator and 50 points to the one with the lowest value).

3. The values obtained in step 2 for each of the basic indicators are summed up for each city and are normalized to a value between 10 and 100.

Assignment of weights

The following weights are used to calculate the final score:



All categories (except for Green Spaces) represent sectors responsible for greenhouse gas emissions. For the purposes of the research, their weights are calculated based on the structure of emissions as submitted by cities to CDP in 2022 [59] (using the most common methodology, the GCoM CRF reporting framework [60], with contributions from more than 200 cities):

- **Energy:** emissions from fuel combustion in stationary sources (direct) and related to the consumption of energy received through distribution networks (indirect)
- **Transport:** emissions from fuel combustion in vehicle engines (direct).

[1] The weights of Energy Consumption and Energy Sources in the total weight of the Energy sector are distributed as 2/3 and 1/3, respectively, since cities have much more influence over the volume of energy consumption than they have over energy generation sources [61].

→ **Waste:** emissions associated with the management of urban waste inside the city (direct) and beyond its boundaries (out of boundary).

The calculation does not consider greenhouse gas emissions from sectors that fall outside the scope of this research: emissions from the wastewater treatment systems, aviation, etc.

Unlike other categories, Green Spaces have the opposite effect of emissions capture and storage. Achieving a net zero at a national level is still expected to leave residual emissions at 18% of the current values [62]. The climate targets of cities suggest that this figure is also relevant for large cities, where the estimates of residual emissions vary from 10% (London [63]) to 20% (Seoul [64] and Paris [65]).

The results of the city ranking using the assigned set of weights have been tested for stability, where the impact of 1 million random sets of weights on the positions of cities in the final ranking has been analyzed.

The stability test has been carried out using simulations that show how the positions of cities in the ranking change when the random sets of weights are "distanced" from the main set of weights.

The simulations have revealed that the positions of cities are stable: for example, if the Euclidean distance between sets of weights does not exceed 10 p.p., the rank correlation coefficient does not fall below 95.