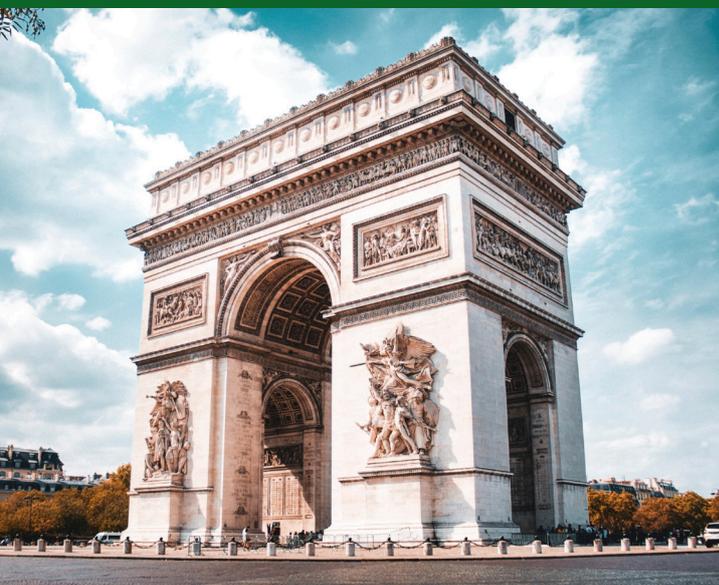


Final Results By Category

Paris

Most of the electricity consumed in Paris is generated outside the city, so its energy consumption structure is largely defined by the national energy system, where a significant part of generation comes from nuclear power. Still, the local government is taking measures to increase the share of renewable sources in the city's energy balance. Since 2016, all electricity purchased by the municipal authorities for street lighting and power supply of municipal buildings has been produced from renewable sources [22]. Electricity suppliers contracted by the city are obliged to provide certificates confirming that the amount of energy produced from renewable sources can cover the amount purchased by the city authorities.

In addition, the municipal area of Paris is implementing a large-scale program to be completed by 2030 to develop its own generating capacity based on renewable energy [23]. The program, at a cost of 46 million euros, is expected to double the amount of energy produced from RESs within the region and increase the share of energy from renewable sources to 40% of total consumption.



Energy Sources

The **power generation sector** is one of the **largest contributors to greenhouse gas emissions** [19]. Switching to cleaner energy sources is a key challenge for the world's megacities.

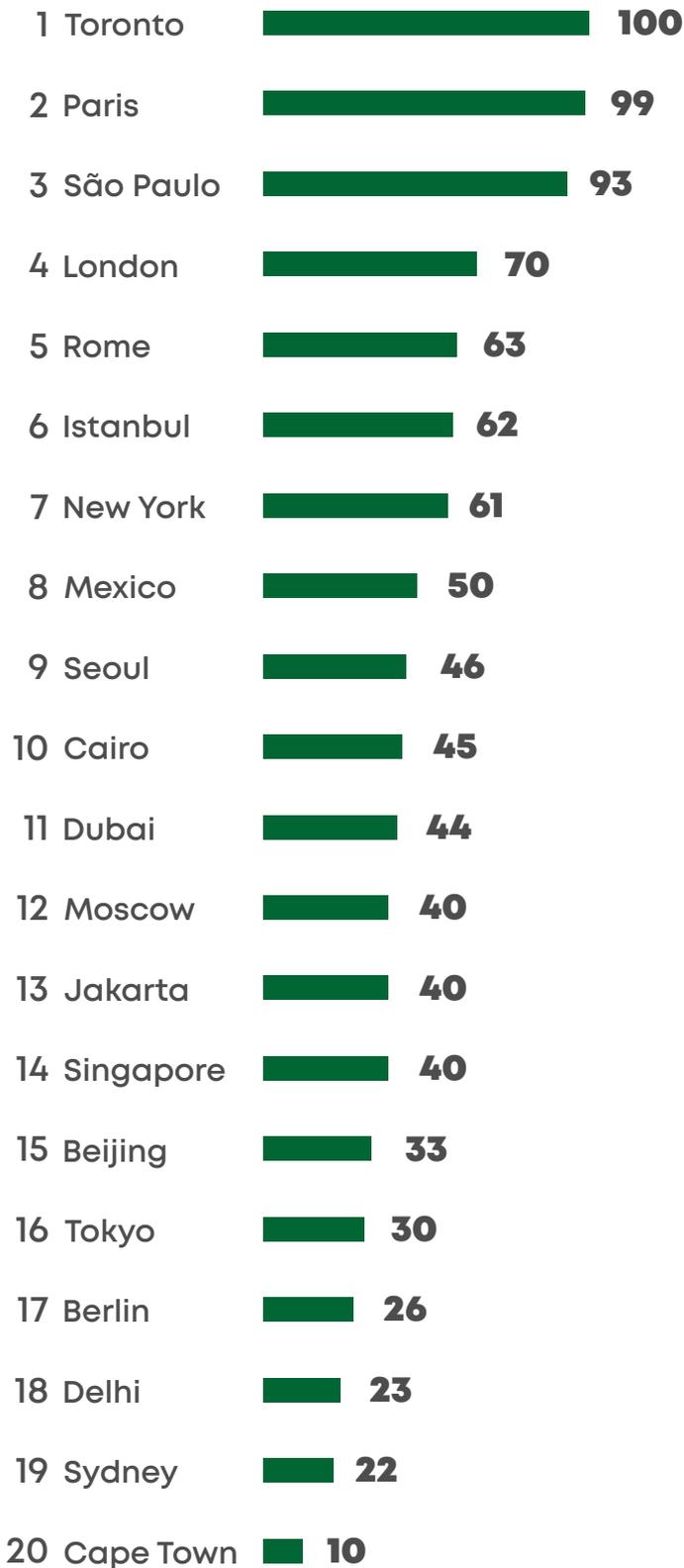
The research compares the energy consumption mix of cities in terms of carbon intensity: the cleaner the energy sources, the higher the score¹

Due to data availability constraints, in some cases national-level energy consumption mix is used to evaluate individual cities. For instance, Paris and London, both ranking high in the category, are evaluated on the national level data. These cities import most of the electricity they consume from other regions, so their sources of energy are largely defined by the structure of the country's overall energy system.

Thus, only 5% of the electricity consumed in the region of Paris is produced on its territory [20], with the balance supplied from other regions of France. The energy system of London is organized in a similar way: the city is supplied with electricity generated by power plants located outside [21].

¹For the purposes of the research, clean energy sources include RESs (solar, wind, hydro, etc.), and nuclear energy, the production of which does not result in greenhouse gas emissions

City Ranking: Energy Sources



São Paulo

About 60% of power generated in the state of São Paulo is produced from RESs [24].

A large proportion of energy is generated by hydro and biomass power plants (mainly using sugarcane waste called bagasse). Today, São Paulo has 128 hydro power plants and 233 thermal power plants that use biomass as fuel. Together, they account for almost 90% of the state's generating capacity [24].

City authorities have placed emphasis on developing solar energy. Since 2007, São Paulo has had a law requiring all new buildings with four or more bathrooms to be equipped with solar water heaters providing at least 40% of the energy required to heat the water [25].



Berlin

Berlin, the city with the highest ranking in this category among all cities in developed countries, was one of the first cities to introduce an energy efficiency retrofit program based on energy service contracts. Later, other cities followed suit; in particular, a similar REFIT program has been successfully operating in London since 2010, and it is expected to be completed in 2025 [27].

In 1996, the Government of Berlin, jointly with the Berlin Energy Agency (BEA), launched a mechanism to attract private funding for energy-efficiency retrofits of public buildings [28] based on energy service contracts between building owners and energy companies. Such contracts require companies to bear the cost of the upgrades, which is then reimbursed by the owner from a portion of their savings on utility bills over the term of the contract (usually 8–12 years).

The BEA acts as the main coordinator at all stages. Among other things, it selects buildings that require modernization, prepares tender procedures, evaluates bids from energy service companies, monitors the process and results, and helps the energy service companies get bank loans.

Over 1,400 public buildings have been renovated under this program. Energy costs have fallen on average by 26%, and the reduction in GHG emissions is estimated at 70,000 t annually [28].

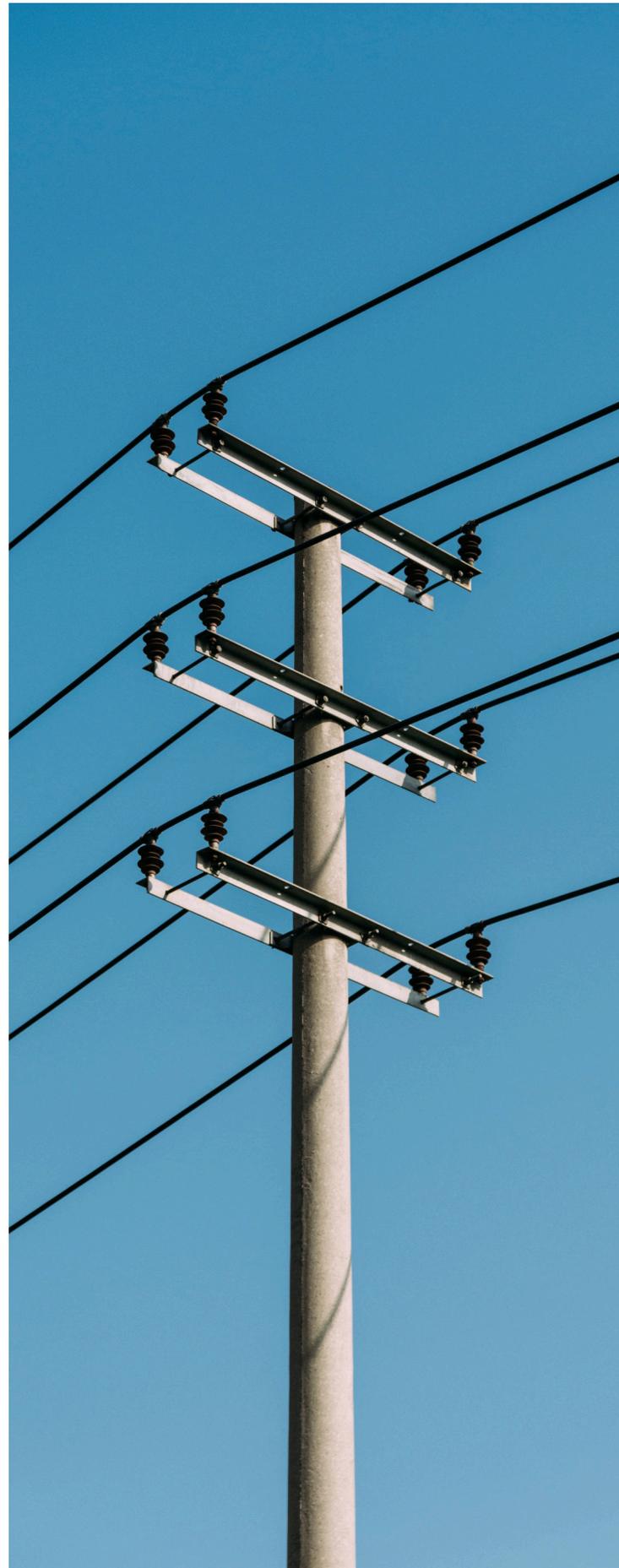
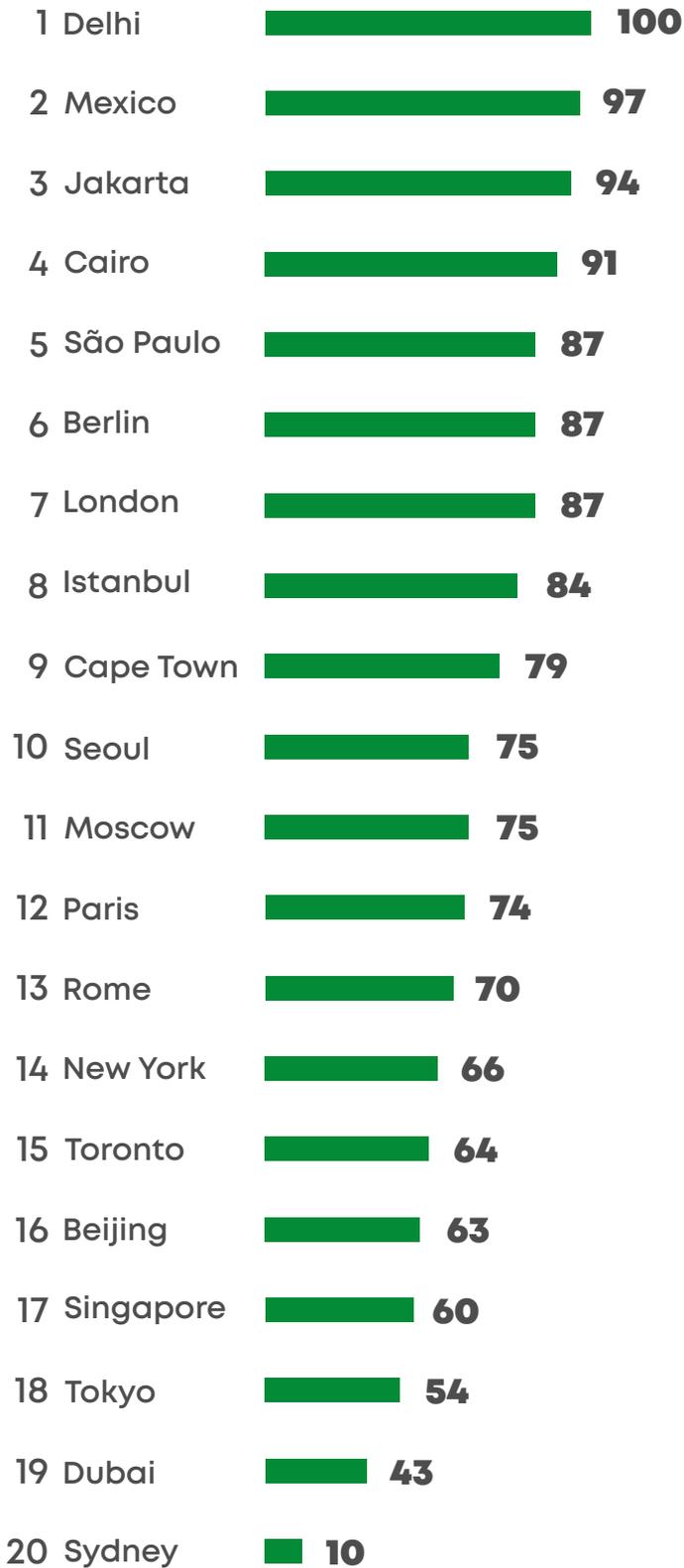
Energy Consumption

The ability of cities to switch to clean energy sources may be limited by factors beyond their control. The potential for solar, wind, and hydropower generation is largely determined by the geographical location of a city and its climate. If cities cannot meet the energy demand from clean sources, they can **reduce the impact on the climate by reducing energy consumption** [26].

To assess the efficiency of their energy consumption, cities were evaluated on the basis of heat and electricity consumption, adjusted for the average annual temperature

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

City Ranking: Energy Consumption



Beijing

Beijing authorities offer market-based incentives encouraging residents to move away from private cars in favor of more environmentally friendly transportation. The system is based on digital technologies, a MaaS platform (Mobility-as-a-Service), which integrates various types of municipal transport. It was developed by the Beijing government in collaboration with major online mapping services.

Since 2020, the platform has hosted a program that rewards users for moving around the city by public transport, bicycle, or walking [30]. The distance commuted by a registered user in such a manner is converted into carbon credits. These are conventional units that show the amount of carbon emissions reduced through the choice of alternative means of transportation to a car. Credits can then be used to donate to charity, pay for public transport, purchase discount coupons or subscribe to online services.

In June 2023, the number of platform users participating in the reward program exceeded 3.5 million people. According to the estimates of the city authorities, the program has helped reduce carbon dioxide emissions by almost 400 000 t in the 3 years it has been used [31].

Transport

Transport systems account for about a third of greenhouse gas emissions in cities [29], and their impact on climate change largely depends on the means of transportation its residents prefer.

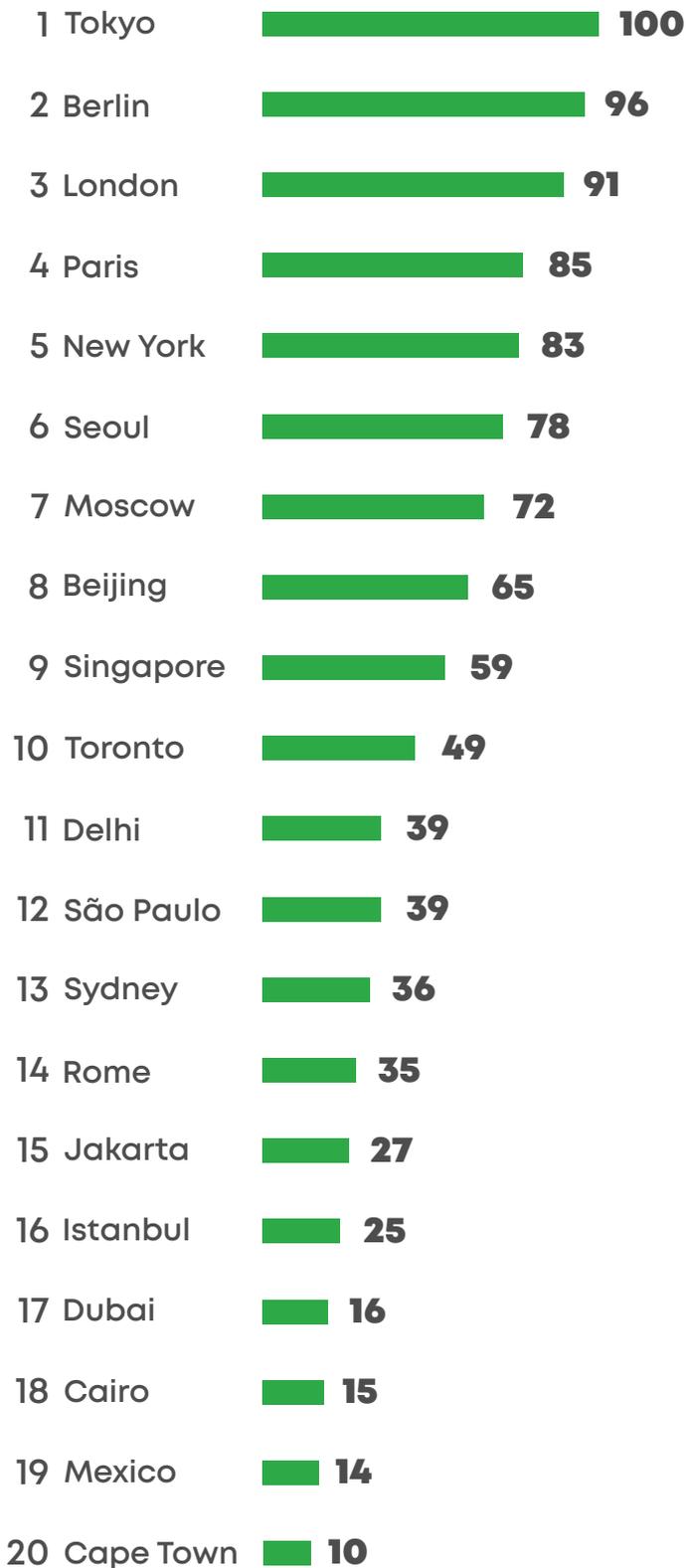
Clean means of transportation are not equipped with internal combustion engines. Instead of fossil fuels they are powered by electricity or hydrogen fuel cells. Such vehicles do not emit greenhouse gases during operation.

In this research, the following are considered clean means of transport: metro and railway, trams, zero-emission buses, private electric cars, bicycles and walking.

In this category, cities are measured by the availability of clean means of transport. The cleaner the city transport is, the higher the score is received



Cities Ranking: Transport



Tokyo

The government of Tokyo has a whole range of measures to decarbonize the municipal transport system [32].

One priority is promoting hydrogen fuel cell vehicles.

Work is underway in partnership with private companies to create appropriate infrastructure, and there is a campaign to win public support for hydrogen vehicles. A museum has been created to promote the use of hydrogen, where visitors learn about the benefits of this type of fuel and can even try to fill their car with it.



Moscow

Moscow is one of the leaders among European capitals in terms of the number of urban green spaces that have a protected status. There are 147 specially protected natural areas (SPNAs) within city limits, with a total area of more than 19,800 ha [36]. Most of these protected areas are classified as those of regional importance, which means they have been created by the city government.

The SPNA status implies that any activity that harms natural objects, flora and fauna, is prohibited within the boundaries of such a territory. Such land cannot be transferred to private or corporate ownership, and the activities that are allowed on the land are subject to a list of permitted activities, which is defined for each particular area taking into account its natural features. Moscow has established a legislative ban on reducing the size of such protected areas or abolishing them.

The number of urban protected areas has been constantly increasing. In 2020–2023 alone, 40 territories with a total area of more than 2,300 ha were given protected status [36].



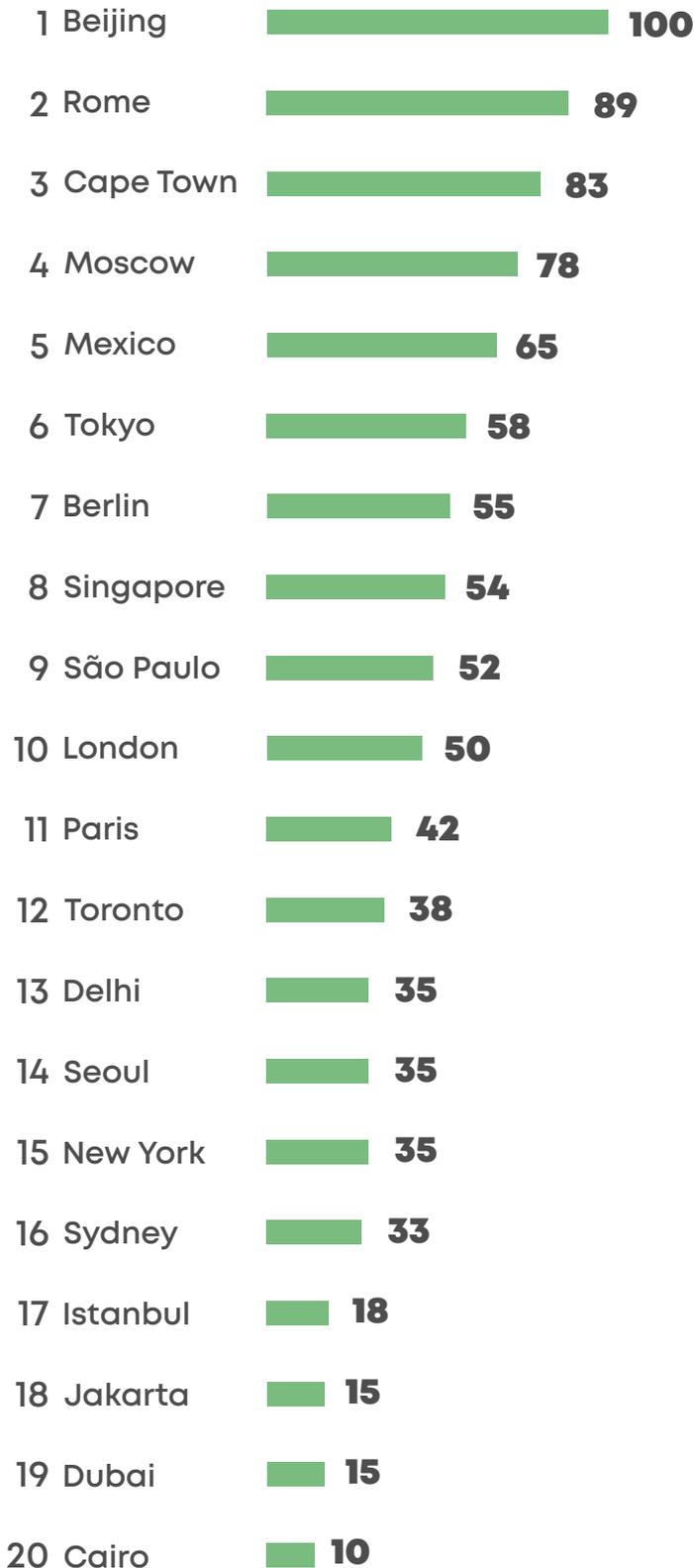
Green Spaces

Urban green spaces have significant potential as natural tools for carbon dioxide capture and storage [33]. By creating more green spaces, a city can offset greenhouse gas emissions that remain despite all the measures taken under other climate programs.

To compare cities in this category, the ratio of the area of green spaces located within its administrative boundaries to the total city area is calculated for each city based on Google Maps data. Cities with a higher proportion of green spaces score higher

The current assessments of the absorptive capacity of urban green spaces differ greatly, because it depends on many factors, including climatic conditions and the composition and density of green spaces [34]. Studies show that in some cases green spaces can absorb more than 20% of the total urban greenhouse gas emissions from fuel combustion [35]. Moreover, the effectiveness of green spaces as a mitigation tool can be enhanced through urban planning. For example, trees planted near buildings are a barrier to wind and sunlight, which helps to reduce the need for energy resources for heating and air conditioning [35].

City Ranking: Green Spaces

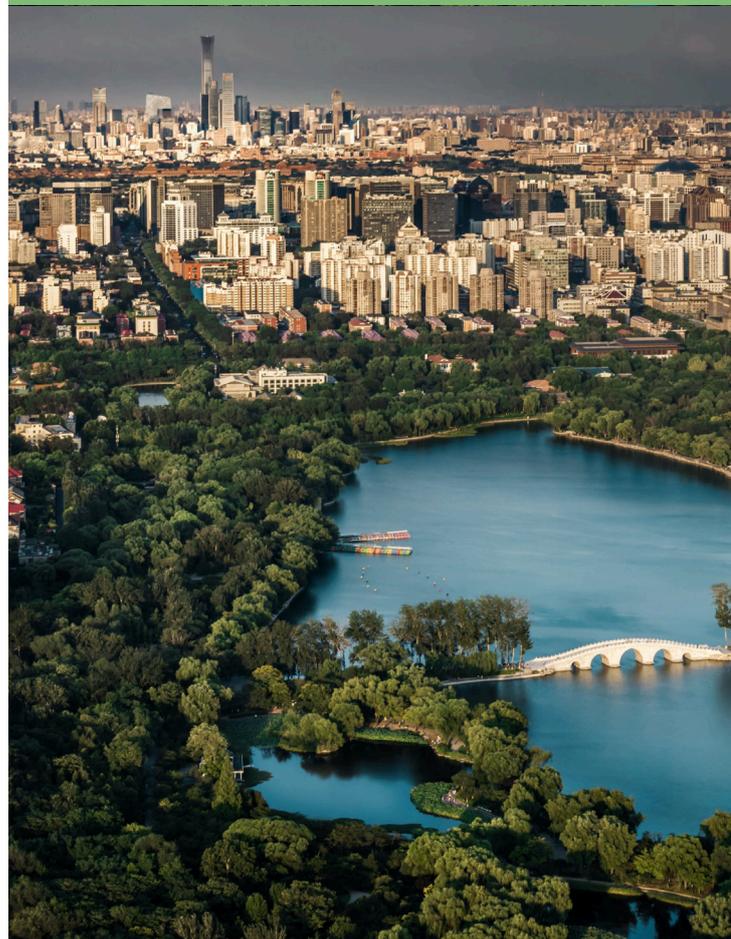


Beijing

China has celebrated National Tree Planting Day every year since the 1980s, with residents and political leaders planting trees with their own hands in city streets and parks.

In 2022, Beijing authorities allocated more than 70 ha of land for the planting of new trees for that day. The process was accompanied by cultural events, where residents could learn about the role of green spaces in the ecosystem of their city and ways to change their lifestyle to reduce its impact on the environment and climate.

The number of trees in Beijing has more than doubled since this holiday was introduced [37].





Waste

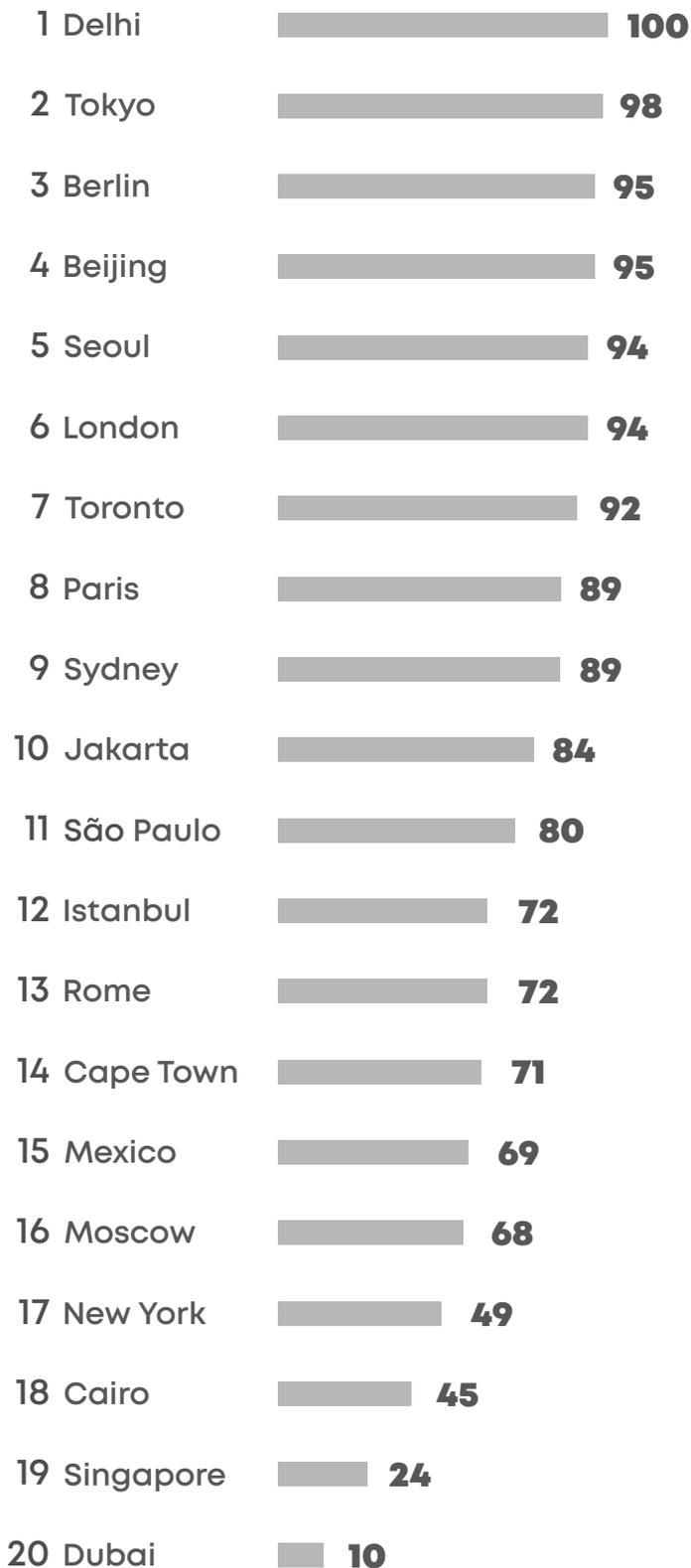
As MSW decomposes, it releases **methane** [38], a **greenhouse gas with a global warming potential 30 times higher than that of carbon dioxide** [1]. Despite the relatively small share of this gas in the total mass of anthropogenic emissions [39], achieving carbon neutrality goals is impossible without taking measures to limit waste generation. Therefore, reducing waste is an important part of the urban climate agenda.

In terms of its impact on climate, it is not only the total amount of waste produced by the city that is important, but also how it is managed. Recycling and reusing waste can significantly reduce greenhouse gas emissions, while waste disposal in landfills increases them [38].

This research assesses both of these aspects: waste generation and waste management.

To compare cities, per capita indicators were used, for both the total mass of MSW production and the mass of waste disposed of in landfills

City Ranking: Waste



Seoul

Since the mid-1990s, South Korea has had a system of waste disposal fees, where people have to pay a certain amount of money in proportion to the amount of waste they generate [40].

This system has made it possible to significantly reduce the volume of waste and increase the amount of recycled waste. In particular, the proportion of recycled waste in Seoul increased by 30% during the functioning of the system, and the amount of generated waste decreased by 8% in the very first year of the program alone [41].

The Seoul government did not stop there, launching a city program to extract metals from electronic waste in 2009 [42]. There is a center to receive scrap consumer electronics, office equipment and mobile phones, where they are disassembled into parts, with the metals then sent for further processing.

The program provides financial incentives for university students: the profits received from the recycling of their mobile phones are paid to students in the form of a stipend increase.

According to the estimates of the Seoul authorities, the program helped reduce greenhouse gas emissions by 120,000 t from 2009 to 2021 [43].



Points Scored by Cities in all Categories

