Supplementary information

Cooling access and energy requirements for adaptation to heat stress in megacities

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1. Input data and projections

1.1. Megacities

We report in Table s1 the set of megacities included in this study. Cities are mapped to the six Global South regions used in the global energy-economy integrated assessment model MESSAGEix (Huppmann et al. 2019): sub-Saharan Africa (AFR), South Asia (SAS), Middle East and North Africa (MEA), Other Pacific Asia (PAS), Centrally planned Asia and China (CPA), and Latin America and the Caribbean (LAM).

| City        | Country   | Region | Climate  | Latitude | Longitude |
|-------------|-----------|--------|----------|----------|-----------|
| Luanda      | Angola    | AFR    | Arid     | -8.84    | 13.29     |
| Kinshasa    | Congo DRC | AFR    | Tropical | -4.30    | 15.30     |
| Lagos       | Nigeria   | AFR    | Tropical | 6.45     | 3.40      |
| Dar es Salaam | Tanzania | AFR    | Tropical | -6.79    | 39.21     |
| Dhaka       | Bangladesh| SAS    | Tropical | 23.72    | 90.41     |
| Karachi     | Pakistan  | SAS    | Arid     | 24.91    | 67.08     |
| Lahore      | Pakistan  | SAS    | Arid     | 31.55    | 74.34     |
| Hyderabad   | India     | SAS    | Tropical | 17.38    | 78.47     |
| Bangalore   | India     | SAS    | Tropical | 12.98    | 77.58     |
| Chennai     | India     | SAS    | Tropical | 13.08    | 80.28     |
| Kolkata     | India     | SAS    | Tropical | 22.57    | 88.37     |
| Delhi       | India     | SAS    | Temperate| 28.60    | 77.20     |
| Mumbai      | India     | SAS    | Tropical | 19.10    | 72.90     |
| Baghdad     | Iraq      | MEA    | Arid     | 33.32    | 44.37     |
| Cairo       | Egypt     | MEA    | Arid     | 30.04    | 31.27     |
| Manila      | Philippines| PAS   | Tropical | 14.63    | 121.02    |
| Jakarta     | Indonesia | PAS    | Tropical | -6.23   | 106.84    |
| Beijing     | China     | CPA    | Cold     | 39.93    | 116.39    |
| Shanghai    | China     | CPA    | Temperate| 29.33    | 121.06    |
| Buenos Aires| Argentina | LAM    | Temperate| -34.60   | -58.38    |
| Rio De Janeiro | Brazil  | LAM    | Tropical | -22.89   | -43.20    |
| Sao Paulo   | Brazil    | LAM    | Temperate| -23.55   | -46.63    |

Notes:

1 Regions in the global energy-economy integrated assessment model MESSAGEix. Further details available at the webpage: [https://iiasa.ac.at/web/home/research/researchPrograms/Energy/MESSAGE-model-regions.en.html](https://iiasa.ac.at/web/home/research/researchPrograms/Energy/MESSAGE-model-regions.en.html)

2 Main climate group according to the Köppen–Geiger climate classification (Peel et al. 2007).

1.2. Climatic data

We calculate cooling degree days based on the spatial dataset described in the main text (section 2.4) of this paper for each of the megacities at their coordinates (Table s1). We report in Table s2 the standard cooling degree days (base 18°C) used to calculate the access to air-conditioning (AC) and in Table s3 the variable degree days (base 26°C) used to assess cooling gaps and energy requirements.
Table s2 Standard cooling degree days (base 18°C) for the set of selected megacities under different climates.

| City          | Country       | Climate 1.5°C | Climate 2°C | Climate 3°C |
|---------------|---------------|---------------|-------------|-------------|
| Kinshasa      | Congo DRC     | 2887          | 3028        | 3498        |
| Lagos         | Nigeria       | 3608          | 3773        | 4221        |
| Luanda        | Angola        | 2720          | 3090        | 3388        |
| Dar es Salaam | Tanzania      | 3050          | 3233        | 3412        |
| Karachi       | Pakistan      | 2968          | 3249        | 3562        |
| Dhaka         | Bangladesh    | 3115          | 2901        | 3250        |
| Lahore        | Pakistan      | 3396          | 3524        | 4117        |
| Hyderabad     | India         | 2875          | 2942        | 3362        |
| Bangalore     | India         | 3161          | 2985        | 3520        |
| Chennai       | India         | 4086          | 4292        | 4628        |
| Kolkata       | India         | 3379          | 3638        | 4012        |
| Delhi         | India         | 3260          | 3855        | 3952        |
| Mumbai        | India         | 3589          | 3756        | 4126        |
| Baghdad       | Iraq          | 1826          | 1926        | 1848        |
| Cairo         | Egypt         | 2021          | 2207        | 2268        |
| Manila        | Philippines   | 3059          | 3171        | 3437        |
| Jakarta       | Indonesia     | 3608          | 3760        | 4038        |
| Shanghai      | China         | 1049          | 1059        | 1276        |
| Beijing       | China         | 1088          | 1136        | 1060        |
| Buenos Aires  | Argentina     | 776           | 786         | 827         |
| Rio De Janeiro| Brazil        | 2053          | 2322        | 2610        |
| São Paulo     | Brazil        | 1063          | 1198        | 1478        |

Table s3 Variable cooling degree days (base 26°C) for the set of selected megacities under different climates.

| City          | Country       | Climate 1.5°C | Climate 2.0°C | Climate 3.0°C |
|---------------|---------------|---------------|---------------|---------------|
| Kinshasa      | Congo DRC     | 510           | 599           | 1059          |
| Lagos         | Nigeria       | 1217          | 1382          | 1828          |
| Luanda        | Angola        | 648           | 848           | 1110          |
| Dar es Salaam | Tanzania      | 755           | 908           | 1080          |
| Karachi       | Pakistan      | 1450          | 1595          | 1827          |
| Dhaka         | Bangladesh    | 1027          | 1187          | 1427          |
| Lahore        | Pakistan      | 1664          | 1500          | 1754          |
| Hyderabad     | India         | 1276          | 1350          | 1848          |
| Bangalore     | India         | 714           | 776           | 1107          |
| Chennai       | India         | 1774          | 1977          | 2312          |
| Kolkata       | India         | 1372          | 1510          | 1813          |
| Delhi         | India         | 1616          | 1446          | 1867          |
| Mumbai        | India         | 1411          | 1566          | 1930          |
| Baghdad       | Iraq          | 640           | 631           | 669           |
| Cairo         | Egypt         | 781           | 932           | 950           |
| Manila        | Philippines   | 658           | 766           | 1033          |
| Jakarta       | Indonesia     | 1192          | 1344          | 1621          |
| Shanghai      | China         | 190           | 216           | 305           |
| Beijing       | China         | 305           | 317           | 276           |
| Buenos Aires  | Argentina     | 139           | 133           | 140           |
| Rio De Janeiro| Brazil        | 307           | 425           | 625           |
| São Paulo     | Brazil        | 37            | 78            | 165           |
1.3. Demographics and socio-economics

Population data for 2010 and predictions for 2050 under SSP1-3 for the selected megacities (Table s4) are from literature (Hoornweg and Pope 2017). We use per-capita GDP projections from a spatially gridded dataset (Murakami and Yamagata 2019) consistent with the SSP framework (Table s5) and select data at the coordinates of the selected megacities. Figure s1 shows a comparison of GDP projections for the set of megacities from the spatially gridded data and urban per-capita GDP projections at national level (Dellink et al. 2017; Riahi et al. 2017).

Table s4 Population projections for the selected megacities based on (Hoornweg and Pope 2017).

| City         | Country     | Population (million) |
|--------------|-------------|-----------------------|
|              | 2010        | 2050 SSP1  | 2050 SSP2  | 2050 SSP3  |
| Kinshasa     | Congo DRC   | 9.1        | 34.4       | 33.3       | 26.3       |
| Lagos        | Nigeria     | 10.6       | 34.3       | 36.3       | 37.5       |
| Luanda       | Angola      | 4.8        | 17.0       | 19.0       | 22.4       |
| Dar es Salaam| Tanzania    | 3.3        | 19.0       | 19.1       | 16.5       |
| Karachi      | Pakistan    | 13.1       | 39.3       | 37.0       | 32.0       |
| Dhaka        | Bangladesh  | 14.8       | 43.9       | 37.5       | 31.8       |
| Lahore       | Pakistan    | 7.1        | 21.4       | 20.1       | 17.4       |
| Hyderabad    | India       | 6.8        | 18.3       | 16.0       | 12.6       |
| Bangalore    | India       | 7.2        | 19.6       | 17.1       | 13.4       |
| Chennai      | India       | 7.6        | 20.4       | 17.9       | 14.1       |
| Kolkata      | India       | 15.6       | 42.1       | 36.8       | 29.0       |
| Delhi        | India       | 17.0       | 46.0       | 40.2       | 31.6       |
| Mumbai       | India       | 20.1       | 54.3       | 47.4       | 37.3       |
| Baghdad      | Iraq        | 5.9        | 14.1       | 15.3       | 15.4       |
| Cairo        | Egypt       | 12.5       | 28.9       | 27.9       | 23.1       |
| Manila       | Philippines | 11.7       | 25.8       | 25.3       | 25.4       |
| Jakarta      | Indonesia   | 9.7        | 19.2       | 18.0       | 15.6       |
| Shanghai     | China       | 15.8       | 24.1       | 22.0       | 19.7       |
| Beijing      | China       | 19.6       | 29.9       | 27.3       | 24.4       |
| Buenos Aires | Argentina   | 13.1       | 16.4       | 18.1       | 20.9       |
| Rio de Janeiro| Brazil     | 12.2       | 14.5       | 15.7       | 17.9       |
| Sao Paulo    | Brazil      | 19.6       | 23.3       | 25.3       | 28.7       |
Table S5 GDP projections for the selected megacities from spatially gridded urban GDP data (Murakami and Yamagata 2019).

| City        | Country   | GDP (US$2005PPP/cap/yr) | 2010 | 2050 SSP1 | 2050 SSP2 | 2050 SSP3 |
|-------------|-----------|-------------------------|------|-----------|-----------|-----------|
| Kinshasa    | Congo DRC | 387                     | 8815 | 4316      | 2420      |
| Lagos       | Nigeria   | 1844                    | 14551| 9916      | 6263      |
| Luanda      | Angola    | 7688                    | 16967| 10109     | 6738      |
| Dar es Salaam | Tanzania | 1928                    | 16868| 9686      | 5639      |
| Karachi     | Pakistan  | 3076                    | 16432| 10971     | 6526      |
| Dhaka       | Bangladesh| 2369                    | 20935| 12009     | 7345      |
| Lahore      | Pakistan  | 3480                    | 16325| 10436     | 6016      |
| Hyderabad   | India     | 4012                    | 29939| 19137     | 11821     |
| Bangalore   | India     | 3019                    | 22805| 15416     | 9490      |
| Chennai     | India     | 3855                    | 31877| 20559     | 11770     |
| Kolkata     | India     | 4242                    | 32781| 20713     | 12118     |
| Delhi       | India     | 6785                    | 48188| 27913     | 15180     |
| Mumbai      | India     | 4212                    | 34775| 22144     | 12733     |
| Baghdad     | Iraq      | 5537                    | 24944| 17515     | 16447     |
| Cairo       | Egypt     | 8326                    | 41145| 29959     | 19790     |
| Manila      | Philippines| 3169                   | 15346| 11087     | 7969      |
| Jakarta     | Indonesia | 5799                    | 46663| 29217     | 19437     |
| Shanghai    | China     | 8058                    | 62481| 45487     | 31773     |
| Beijing     | China     | 12933                   | 91664| 61499     | 39427     |
| Buenos Aires| Argentina | 19669                   | 64235| 49836     | 33358     |
| Rio de Janeiro| Brazil  | 18574                   | 60431| 39620     | 26345     |
| Sao Paulo   | Brazil    | 18022                   | 56233| 36611     | 25790     |

Figure S1 Comparison of GDP projections for the selected cities from spatially gridded data (Murakami and Yamagata 2019) and national urban averages (Dellink et al. 2017; Riahi et al. 2017).
1.4. Housing characteristics and cooling systems

We assume minimum floorspace thresholds of 10m² per-capita, with minimum 30 m² for households with up to 3 persons. These thresholds are from previous work (Rao and Min 2017; Kikstra et al. 2021) and were identified based on national guidelines for affluent, but densely populated countries. By combining household size distribution in countries (United Nations 2019) with the above per capita floorspace thresholds (Kikstra et al. 2021), we derive average per-capita floorspace values by country and attribute them to the set of megacities (Table s6).

Housing characteristics are based on the urban housing archetype identified in prior work (Mastrucci et al. 2019) and representing prevailing construction practices in the global South (Table s7). The urban housing archetype is a four-storey building with concrete framing and roofing, brick masonry, and single-glazing windows. The main building characteristics are defined based on a review of housing with durable materials in developing countries in existing literature (Mastrucci et al. 2019), to which we refer for more detailed information. Equipment for space cooling includes AC systems with 2.9 energy efficiency ratio (EER), corresponding to the current average in developing countries (IEA 2018). We consider here AC as one of the most common technologies to provide space cooling.

| City          | Country      | Floorspace (m²/cap) |
|---------------|--------------|---------------------|
| Kinshasa      | Congo DRC    | 10.56               |
| Lagos         | Nigeria      | 10.87               |
| Luanda        | Angola       | 10.80               |
| Dar es Salaam | Tanzania     | 10.77               |
| Karachi       | Pakistan     | 10.17               |
| Dhaka         | Bangladesh   | 10.44               |
| Lahore        | Pakistan     | 10.17               |
| Hyderabad     | India        | 10.52               |
| Bangalore     | India        | 10.52               |
| Chennai       | India        | 10.52               |
| Kolkata       | India        | 10.52               |
| Delhi         | India        | 10.52               |
| Mumbai        | India        | 10.52               |
| Baghdad       | Iraq         | 10.14               |
| Cairo         | Egypt        | 10.71               |
| Manila        | Philippines  | 10.85               |
| Jakarta       | Indonesia    | 10.87               |
| Shanghai      | China        | 11.78               |
| Beijing       | China        | 11.78               |
| Buenos Aires  | Argentina    | 11.76               |
| Rio De Janeiro| Brazil       | 11.46               |
| Sao Paulo     | Brazil       | 11.46               |
Table s7 Characteristics of the building envelope components in the urban archetype based on (Mastrucci et al. 2019).

| Envelope component | Material      | U-value (W/m²K) | Envelope component area on floorspace area (m²/m²) |
|--------------------|---------------|-----------------|--------------------------------------------------|
| Walls              | Fired bricks  | 2.10            | 0.985                                            |
| Roof               | Concrete      | 2.06            | 0.250                                            |
| Windows            | Single-glazing| 5.79            | 0.125                                            |
| Total envelope     |               | 2.18*           | 1.610                                            |

Note: *Weighted average on building components

2. Detailed results

2.1. Access to air conditioning

We report here below the projections of AC access (Table s8) and total population with AC access (Table s9) for the set of selected megacities, estimated for the base year 2010 and for 2050 under different SSPs and climate futures. AC access was calculated based on methods in literature (McNeil and Letschert 2008; Isaac and van Vuuren 2009).

We correct AC access values for the base year to better match existing data and literature. Empirical data on ownership of AC in cities is limited and available only for few locations and years (Table s10). Previous works have compared the results of the AC access model used in this study against measured data at national level (Mastrucci et al. 2019, 2021), showing some discrepancies for specific regions, including CPA, MEA, PAS, and SAS. We use the results of previous comparisons (Mastrucci et al. 2021) to rescale AC access values estimated by the empirical model in the base year. After rescaling, the comparison with available measured data provided satisfactory agreement, except for the cities in CPA (Shanghai and Beijing). For these cities, we apply a correction based on the measured results from literature (Hu et al. 2019) and accounting for the time difference between the base year (2010) and year of the survey (2015). While such discrepancies were found in Shanghai and Beijing for the base year, we note that projections of future AC access approach saturation levels, and therefore do not require further corrections.
Table s8 Projections of AC access for the selected megacities in different scenarios. For the base year (2010), “Estim.” denotes values estimated using the AC adoption model and “Corr.” values corrected based on existing data and literature.

| City          | Country   | 2010   | 2050   | 2050   | 2050  | 2050  |
|---------------|-----------|--------|--------|--------|-------|-------|
|               |           | AC access (%) |      |      |      |      |      |
|               |           | Estim. | Corr.  | 1.5°C | 2°C  | 3°C  | 1.5°C | 2°C  | 3°C  | 1.5°C | 2°C  | 3°C  |
| Kinshasa      | Congo DRC| 1.7    | 11.2   | 11.2  | 11.3 | 4.2  | 4.2   | 4.2  | 2.7  | 2.7  | 2.7  |
| Lagos         | Nigeria   | 2.4    | 33.1   | 33.1  | 33.1 | 14.1 | 14.2  | 14.2 | 6.5  | 6.5  | 6.5  |
| Luanda        | Angola    | 8.8    | 46.5   | 46.6  | 46.7 | 14.6 | 14.7  | 14.7 | 7.2  | 7.2  | 7.2  |
| Dar es Salaam | Tanzania  | 2.4    | 46     | 46    | 46.1 | 13.5 | 13.5  | 13.5 | 5.6  | 5.6  | 5.6  |
| Karachi       | Pakistan  | 3.1    | 9.5    | 43.5  | 43.5 | 43.6 | 17.5  | 17.5 | 17.5 | 6.9  | 6.9  | 6.9  |
| Dhaka         | Bangladesh| 2.7    | 68.9   | 69    | 69.1 | 21.2 | 21.3  | 21.3 | 8.2  | 8.2  | 8.2  |
| Lahore        | Pakistan  | 3.4    | 10.4   | 42.9  | 42.8 | 42.9 | 15.7  | 15.7 | 15.7 | 6.1  | 6.1  | 6.1  |
| Hyderabad     | India     | 3.9    | 11.8   | 94.8  | 94.9 | 95   | 59.4  | 59.4 | 59.4 | 20.5 | 20.6 | 20.6 |
| Bangalore     | India     | 3.1    | 9.4    | 77.4  | 77.5 | 77.6 | 37.6  | 37.6 | 37.6 | 12.9 | 12.9 | 12.9 |
| Chennai       | India     | 3.8    | 11.4   | 96.7  | 96.7 | 96.8 | 67.2  | 67.2 | 67.2 | 20.4 | 20.4 | 20.4 |
| Kolkata       | India     | 4.1    | 12.5   | 97.2  | 97.3 | 97.3 | 68    | 68   | 68   | 21.7 | 21.7 | 21.7 |
| Delhi         | India     | 7.2    | 22.0   | 99.7  | 99.6 | 99.8 | 91.9  | 91.8 | 92   | 36.4 | 36.4 | 36.4 |
| Mumbai        | India     | 4.1    | 12.4   | 98.2  | 98.3 | 98.3 | 74.9  | 74.9 | 74.9 | 24.3 | 24.3 | 24.3 |
| Baghdad       | Iraq      | 5.1    | 36.7   | 82.7  | 83.1 | 82.8 | 48.4  | 48.7 | 48.5 | 42.3 | 42.5 | 42.4 |
| Cairo         | Egypt     | 9.7    | 97.5   | 98.1  | 98.3 | 93   | 93.6  | 93.7 | 93.7 | 61.8 | 62.2 | 62.3 |
| Manila        | Philippines | 3.2   | 6.1    | 37.3  | 37.3 | 37.3 | 17.8  | 17.8 | 17.9 | 9.4  | 9.4  | 9.4  |
| Jakarta       | Indonesia | 5.8    | 11.1   | 99.8  | 99.8 | 99.9 | 94    | 94   | 94   | 61.1 | 61.1 | 61.1 |
| Shanghai      | China     | 8.0    | 83.0   | 86.7  | 86.9 | 91.3 | 86.5  | 86.8 | 86.8 | 84   | 84   | 88.3 |
| Beijing       | China     | 21.3   | 81.0   | 87.6  | 88.7 | 86.9 | 87.6  | 88.7 | 86.9 | 87.1 | 88.2 | 86.4 |
| Buenos Aires  | Argentina | 45.8   | 77.8   | 78.2  | 79.8 | 77.7 | 78.1  | 78.1 | 79.8 | 76   | 76.4 | 78   |
| Rio De Janeiro| Brazil    | 54.6   | 98     | 98.8  | 99.3 | 97.4 | 98.2  | 98.2 | 98.8 | 87.2 | 87.9 | 88.4 |
| Sao Paulo     | Brazil    | 42.7   | 87     | 89.9  | 94   | 86.1 | 88.9  | 93   | 71   | 73.3 | 76.7 |
Table S9 Projections of population with AC access (million people) in different scenarios for the selected megacities.

| City       | Country      | 2010 | 2050 SSP1 | 2050 SSP2 | 2050 SSP3 |
|------------|--------------|------|-----------|-----------|-----------|
|            |              | 1.5°C| 2.0°C     | 3.0°C     | 1.5°C     | 2.0°C     | 3.0°C     | 1.5°C     | 2.0°C     | 3.0°C     |
| Kinshasa   | Congo DRC    | 0.15 | 3.86      | 3.87      | 3.88      | 1.39      | 1.39      | 1.4       | 0.71      | 0.71      | 0.71      |
| Lagos      | Nigeria      | 0.25 | 11.34     | 11.35     | 11.35     | 5.14      | 5.14      | 5.14      | 2.43      | 2.43      | 2.44      |
| Luanda     | Angola       | 0.42 | 7.89      | 7.91      | 7.92      | 2.77      | 2.78      | 2.79      | 1.6       | 1.61      | 1.61      |
| Dar es Salaam | Tanzania | 0.08 | 8.75      | 8.75      | 8.76      | 2.57      | 2.57      | 2.57      | 0.93      | 0.93      | 0.93      |
| Karachi    | Pakistan     | 1.25 | 17.12     | 17.12     | 17.13     | 6.43      | 6.46      | 6.46      | 2.2       | 2.2        | 2.2       |
| Dhaka      | Bangladesh   | 0.4  | 30.3      | 30.34     | 30.37     | 7.96      | 7.97      | 7.98      | 2.61      | 2.61      | 2.62      |
| Lahore     | Pakistan     | 0.74 | 9.16      | 9.14      | 9.16      | 3.15      | 3.15      | 3.15      | 1.06      | 1.06      | 1.06      |
| Hyderabad  | India        | 0.8  | 16.46     | 16.46     | 16.46     | 9.48      | 9.48      | 9.49      | 2.58      | 2.58       | 2.59      |
| Bangalore  | India        | 0.68 | 15.14     | 15.15     | 15.18     | 6.42      | 6.43      | 6.44      | 1.74      | 1.74       | 1.74      |
| Chennai    | India        | 0.87 | 18.64     | 18.64     | 18.64     | 12        | 12.01     | 12.01     | 2.86      | 2.86       | 2.86      |
| Kolkata    | India        | 1.94 | 38.63     | 38.63     | 38.63     | 25        | 25.02     | 25.03     | 6.29      | 6.29       | 6.3       |
| Delhi      | India        | 3.74 | 45.44     | 45.44     | 45.44     | 35.66     | 35.66     | 35.66     | 11.51     | 11.5       | 11.53     |
| Mumbai     | India        | 2.49 | 50.36     | 50.36     | 50.36     | 35.49     | 35.5      | 35.52     | 9.07      | 9.08       | 9.08      |
| Baghdad    | Iraq         | 2.16 | 11.66     | 11.73     | 11.68     | 7.41      | 7.45      | 7.42      | 6.53      | 6.57       | 6.54      |
| Cairo      | Egypt        | 1.21 | 27.66     | 27.66     | 27.66     | 25.12     | 25.12     | 25.12     | 14.25     | 14.35      | 14.37     |
| Manila     | Philippines  | 0.71 | 9.63      | 9.63      | 9.64      | 4.52      | 4.52      | 4.52      | 2.38      | 2.38       | 2.39      |
| Jakarta    | Indonesia    | 1.08 | 18.84     | 18.84     | 18.84     | 16.15     | 16.15     | 16.15     | 9.52      | 9.52       | 9.52      |
| Shanghai   | China        | 10.42| 20.86     | 20.92     | 21.97     | 19        | 19.06     | 20.01     | 16.49     | 16.54      | 17.37     |
| Beijing    | China        | 14.64| 26.19     | 26.51     | 25.99     | 23.89     | 24.18     | 23.7      | 21.29     | 21.55      | 21.13     |
| Buenos Aires | Argentina | 5.99 | 12.76     | 12.83     | 13.09     | 14.08     | 14.16     | 14.45     | 15.85     | 15.93      | 16.26     |
| Rio De Janeiro | Brazil     | 6.64 | 14.18     | 14.3      | 14.37     | 14.97     | 14.97     | 14.97     | 15.57     | 15.66      | 15.66     |
| Sao Paulo  | Brazil       | 8.37 | 20.26     | 20.94     | 21.9      | 21.79     | 22.51     | 23.54     | 20.39     | 21.07      | 22.03     |
### Table s10 Comparison of AC access estimations with measured data for selected megacities.

| City     | Country | AC access (%) | Year measured value | Source measured data |
|----------|---------|---------------|----------------------|----------------------|
|          |         | Model estimation (2010) | Corrected value (2010) | Measured value |
|          |         |                |                      |                      |
| Delhi    | India   | 7.2           | 22.0                | 24                   | 2016-17        | (Khosla et al. 2021) |
| Jakarta  | Indonesia | 5.8       | 11.1                | 6-89*               | 2012          | (Surahman and Kubota 2018) |
| Shanghai | China   | 8.0           | 83.0                | 87                  | 2015          | (Hu et al. 2019) |
| Beijing  | China   | 21.3          | 81.0                | 85                  | 2015          | (Hu et al. 2019) |
| Rio de Janeiro | Brazil | 54.6         | -                   | 47**                | 2017          | (Pavanello et al. 2021) |

Note: *Range based on different housing types, from simple to luxurious. **Value for the state of Rio de Janeiro.

To further characterize uncertainty, we analysis the sensitivity of the AC access results to the main input values, Cooling Degree Days (CDD) and per-capita GDP, by varying them in the range ±10%. Figure s2 shows that varying CDD values has a limited effect on AC access results, as they define the saturation level. The effect is more significant on locations with lower level of CDD. Conversely, varying per-capita GDP inputs substantially affects AC access levels. In the base year, uncertainties are higher for the cities with higher per-capita GDP, including CPA and LAM. In 2050, uncertainties are higher for cities with medium per-capita GDP in the analyzed range, including cities in SAS and PAS, and limited to SSP1, cities in AFR.

#### 2.1. Slums

We report in Table s11 the share of slum population for the set of megacities, based on the national values estimated according to (Mastrucci et al. 2021). The share of slum population is bounded between 0% and 100%. We analysis the uncertainty on slum projections by varying the per-capita GDP by ±10% and report results in Figure s3. The effect of varying per-capita GDP on the share of slum population is comparable across different GDP levels.

#### 2.1. Cooling gaps

We report in this section the complete results of the cooling gap analysis for the set of selected megacities under different SSPs and climate futures, including total population affected by cooling gap (Table s12), population affected by the cooling gap living in slums (Table s13), and the cities with highest cooling gaps (Table s14).
Figure s2 Results of the sensitivity analysis of AC access to the main model input drivers. Whiskers indicate the effect of varying cooling degree days (top panel) and per-capita GDP (bottom panel) by ±10%.
Table s11 Projection of share of slum population in urban for the selected megacities based on national values (Mastrucci et al. 2021).

| City          | Country       | 2010 | 2050 SSP1 | 2050 SSP2 | 2050 SSP3 |
|---------------|---------------|------|-----------|-----------|-----------|
| Kinshasa      | Congo DRC     | 89.5 | 32.4      | 45.4      | 56        |
| Lagos         | Nigeria       | 61   | 23.2      | 30.2      | 38.6      |
| Luanda        | Angola        | 34.9 | 20.4      | 29.9      | 37.3      |
| Dar es Salaam | Tanzania      | 60.2 | 20.5      | 30.6      | 40.5      |
| Karachi       | Pakistan      | 51.6 | 21        | 28.4      | 37.9      |
| Dhaka         | Bangladesh    | 56.4 | 16.5      | 26.7      | 35.7      |
| Lahore        | Pakistan      | 49.4 | 21.1      | 29.3      | 39.4      |
| Hyderabad     | India         | 46.8 | 10        | 18.2      | 27        |
| Bangalore     | India         | 52   | 15        | 22.1      | 31        |
| Chennai       | India         | 47.5 | 8.8       | 16.9      | 27.1      |
| Kolkata       | India         | 45.7 | 8.3       | 16.7      | 26.5      |
| Delhi         | India         | 37.1 | 1.3       | 11.3      | 22.4      |
| Mumbai        | India         | 45.9 | 7.2       | 15.5      | 25.6      |
| Baghdad       | Iraq          | 40.9 | 13.3      | 19.8      | 20.9      |
| Cairo         | Egypt         | 33.4 | 4.2       | 10        | 17.6      |
| Manila        | Philippines   | 51.1 | 22.2      | 28.2      | 34.2      |
| Jakarta       | Indonesia     | 40   | 1.9       | 10.4      | 17.9      |
| Shanghai      | China         | 34   | 0         | 2.3       | 8.9       |
| Beijing       | China         | 25.3 | 0         | 0         | 4.9       |
| Buenos Aires  | Argentina     | 17.7 | 0         | 0.7       | 8         |
| Rio De Janeiro| Brazil        | 18.7 | 0         | 4.9       | 12.3      |
| Sao Paulo     | Brazil        | 19.3 | 0         | 6.3       | 14.2      |

Figure s3 Results of the sensitivity analysis of slum projections to the main model input drivers. Whiskers indicate the effect of varying per-capita GDP by ±10%.
| City       | Country        | 2010 | 2050 SSP1 | 2050 SSP2 | 2050 SSP3 |
|------------|----------------|------|-----------|-----------|-----------|
| Total cooling gap (million people) |
| 1.5°C | 2.0°C | 3.0°C | 1.5°C | 2.0°C | 3.0°C | 1.5°C | 2.0°C | 3.0°C |
| Kinshasa  | Congo DRC     | 8.9  | 30.55     | 30.55     | 30.54     | 31.93     | 31.93     | 31.93     | 25.55     | 25.54     | 25.54     |
| Lagos     | Nigeria       | 10.32| 22.96     | 22.95     | 22.95     | 31.18     | 31.18     | 31.18     | 35.11     | 35.11     | 35.1      |
| Luanda    | Angola        | 4.35 | 9.09      | 9.07      | 9.06      | 16.18     | 16.17     | 16.17     | 20.75     | 20.75     | 20.75     |
| Dar es Salaam | Tanzania | 3.24 | 10.27     | 10.26     | 10.25     | 16.51     | 16.51     | 16.51     | 15.54     | 15.54     | 15.54     |
| Karachi   | Pakistan      | 11.81| 22.21     | 22.2      | 22.19     | 30.52     | 30.52     | 30.52     | 29.77     | 29.77     | 29.77     |
| Dhaka     | Bangladesh    | 14.4 | 13.65     | 13.6      | 13.57     | 29.51     | 29.49     | 29.49     | 29.21     | 29.2      | 29.2      |
| Lahore    | Pakistan      | 6.35 | 12.21     | 12.23     | 12.21     | 16.94     | 16.95     | 16.94     | 16.3      | 16.3      | 16.3      |
| Hyderabad | India         | 5.96 | 1.83      | 1.83      | 1.83      | 6.49      | 6.48      | 6.48      | 9.99      | 9.99      | 9.98      |
| Bangalore | India         | 6.55 | 4.41      | 4.4       | 4.37      | 10.65     | 10.65     | 10.65     | 11.71     | 11.7      | 11.7      |
| Chennai   | India         | 6.69 | 1.81      | 1.81      | 1.81      | 5.85      | 5.85      | 5.85      | 11.19     | 11.19     | 11.19     |
| Kolkata   | India         | 13.63| 3.51      | 3.51      | 3.51      | 11.79     | 11.77     | 11.76     | 22.67     | 22.67     | 22.67     |
| Delhi     | India         | 13.28| 0.59      | 0.59      | 0.59      | 4.53      | 4.53      | 4.53      | 20.12     | 20.14     | 20.11     |
| Mumbai    | India         | 17.58| 3.93      | 3.93      | 3.93      | 11.91     | 11.9      | 11.89     | 28.25     | 28.25     | 28.24     |
| Baghdad   | Iraq          | 3.73 | 2.45      | 2.38      | 2.43      | 7.9       | 7.85      | 7.89      | 8.91      | 8.87      | 8.9       |
| Cairo     | Egypt         | 11.29| 1.2       | 1.2       | 1.2       | 2.78      | 2.78      | 2.78      | 8.82      | 8.73      | 8.7       |
| Manila    | Philippines   | 10.95| 16.19     | 16.19     | 16.18     | 20.82     | 20.81     | 20.81     | 22.98     | 22.97     | 22.97     |
| Jakarta   | Indonesia     | 8.63 | 0.36      | 0.36      | 0.36      | 1.88      | 1.88      | 1.88      | 6.06      | 6.06      | 6.05      |
| Shanghai  | China          | 5.37 | 3.21      | 3.15      | 2.1       | 2.95      | 2.9       | 2.9       | 3.19      | 3.14      | 3.1       |
| Beijing   | China          | 4.97 | 3.71      | 3.39      | 3.91      | 3.38      | 3.09      | 3.57      | 3.15      | 2.89      | 3.31      |
| Buenos Aires | Argentina | 7.1  | 3.65      | 3.58      | 3.32      | 4.04      | 3.96      | 3.67      | 5.01      | 4.93      | 4.6       |
| Rio De Janeiro | Brazil | 5.53 | 0.3       | 0.18      | 0.1       | 0.76      | 0.76      | 0.76      | 2.29      | 2.2       | 2.2       |
| Sao Paulo | Brazil        | 11.21| 3.03      | 2.35      | 1.4       | 3.53      | 2.8       | 1.77      | 8.35      | 7.67      | 6.7       |
| City       | Country          | Population living in slums (million) |
|------------|------------------|--------------------------------------|
|            |                  | 2010 1.5°C | 2050 SSP1 1.5°C | 2050 SSP2 1.5°C | 2050 SSP3 1.5°C | 2010 2.0°C | 2050 SSP1 2.0°C | 2050 SSP2 2.0°C | 2050 SSP3 2.0°C | 2010 3.0°C | 2050 SSP1 3.0°C | 2050 SSP2 3.0°C | 2050 SSP3 3.0°C |
| Kinshasa   | Congo DRC       | 8.11      | 11.14          | 11.14          | 15.14          | 15.14          | 14.71      | 14.71          | 14.71          | 14.71      | 14.71      | 14.71          | 14.71          |
| Lagos      | Nigeria         | 6.45      | 7.95           | 7.95           | 10.97          | 10.97          | 10.97      | 10.97          | 10.97          | 10.97      | 10.97      | 10.97          | 10.97          |
| Luanda     | Angola          | 1.66      | 3.46           | 3.46           | 5.66           | 5.66           | 5.66       | 8.33           | 8.33           | 8.33       | 8.33       | 8.33           | 8.33           |
| Dar es Salaam | Tanzania     | 2         | 3.89           | 3.89           | 5.85           | 5.85           | 5.85       | 6.67           | 6.67           | 6.67       | 6.67       | 6.67           | 6.67           |
| Karachi    | Pakistan        | 6.74      | 8.24           | 8.24           | 10.48          | 10.48          | 10.48      | 12.1           | 12.1           | 12.1       | 12.1       | 12.1           | 12.1           |
| Dhaka      | Bangladesh      | 8.35      | 7.26           | 7.26           | 10             | 10             | 10         | 11.36          | 11.36          | 11.36      | 11.36      | 11.36          | 11.36          |
| Lahore     | Pakistan        | 3.5       | 4.51           | 4.51           | 5.88           | 5.88           | 5.88       | 6.83           | 6.83           | 6.83       | 6.83       | 6.83           | 6.83           |
| Hyderbad   | India           | 3.16      | 1.83           | 1.83           | 2.9            | 2.9            | 2.9         | 3.39           | 3.39           | 3.39       | 3.39       | 3.39           | 3.39           |
| Bangalore  | India           | 3.76      | 2.93           | 2.93           | 3.78           | 3.78           | 3.78       | 4.17           | 4.17           | 4.17       | 4.17       | 4.17           | 4.17           |
| Chennai    | India           | 3.59      | 1.81           | 1.81           | 3.01           | 3.01           | 3.01       | 3.8            | 3.8            | 3.8        | 3.8        | 3.8            | 3.8            |
| Kolkata    | India           | 7.13      | 3.51           | 3.51           | 6.15           | 6.15           | 6.15       | 7.69           | 7.69           | 7.69       | 7.69       | 7.69           | 7.69           |
| Delhi      | India           | 6.32      | 0.59           | 0.59           | 4.53           | 4.53           | 4.53       | 7.09           | 7.09           | 7.09       | 7.09       | 7.09           | 7.09           |
| Mumbai     | India           | 9.21      | 3.93           | 3.93           | 7.35           | 7.35           | 7.35       | 9.57           | 9.57           | 9.57       | 9.57       | 9.57           | 9.57           |
| Baghdad    | Iraq            | 2.41      | 1.88           | 1.88           | 3.03           | 3.03           | 3.03       | 3.23           | 3.23           | 3.23       | 3.23       | 3.23           | 3.23           |
| Cairo      | Egypt           | 4.18      | 1.2            | 1.2            | 2.78           | 2.78           | 2.78       | 4.05           | 4.05           | 4.05       | 4.05       | 4.05           | 4.05           |
| Manila     | Philippines     | 5.96      | 5.74           | 5.74           | 7.13           | 7.13           | 7.13       | 8.67           | 8.67           | 8.67       | 8.67       | 8.67           | 8.67           |
| Jakarta    | Indonesia       | 3.88      | 0.36           | 0.36           | 1.88           | 1.88           | 1.88       | 2.79           | 2.79           | 2.79       | 2.79       | 2.79           | 2.79           |
| Shanghai   | China           | 5.37      | 0              | 0              | 0.51           | 0.51           | 0.51       | 1.75           | 1.75           | 1.75       | 1.75       | 1.75           | 1.75           |
| Beijing    | China           | 4.97      | 0              | 0              | 0              | 0              | 0         | 1.21           | 1.21           | 1.21       | 1.21       | 1.21           | 1.21           |
| Buenos Aires | Argentina   | 2.31      | 0              | 0              | 0.12           | 0.12           | 0.12       | 1.67           | 1.67           | 1.67       | 1.67       | 1.67           | 1.67           |
| Rio De Janeiro | Brazil     | 2.28      | 0              | 0              | 0.76           | 0.76           | 0.76       | 2.2            | 2.2            | 2.2        | 2.2        | 2.2            | 2.2            |
| Sao Paulo  | Brazil          | 3.77      | 0              | 0              | 1.6            | 1.6            | 1.6         | 4.08           | 4.08           | 4.08       | 4.08       | 4.08           | 4.08           |
Table s14 Cities with the highest cooling gaps in 2050 under different SSPs and 2.0°C climate.

|   | 2050 – SSP1 (million people) |   | 2050 – SSP2 (million people) |   | 2050 – SSP3 (million people) |
|---|-------------------------------|---|-------------------------------|---|-------------------------------|
| 1. Kinshasa | 30.5 | 1. Kinshasa | 31.9 | 1. Lagos | 35.1 |
| 2. Lagos | 23.0 | 2. Lagos | 31.1 | 2. Karachi | 29.8 |
| 3. Karachi | 22.2 | 3. Karachi | 30.5 | 3. Dhaka | 29.2 |
| 4. Manila | 16.2 | 4. Dhaka | 29.5 | 4. Mumbai | 28.2 |
| 5. Dhaka | 13.6 | 5. Manila | 20.8 | 5. Kinshasa | 25.5 |

2.2. Energy requirements

We report in this section the complete results of the analysis of minimum energy requirements for basic cooling comfort for the set of selected megacities under different SSPs and climate futures, including energy intensities (Table s15), total energy demand under projected AC access (Table s16), total energy requirements under universal access to cooling comfort (Table s17), and the cities with highest energy requirements under universal access to cooling comfort (Table s18).

Table s15 Energy intensity for basic space cooling for the set of selected megacities under different climates.

| City     | Country     | Energy intensity (kWh/m²/yr) | Climate       |
|----------|-------------|-----------------------------|---------------|
|          |             |                             | Current | 1.5°C | 2.0°C | 3.0°C |
| Kinshasa | Congo DRC   | 7.80                        | 9.29    | 10.28 | 12.54 |
| Lagos    | Nigeria     | 11.74                       | 12.94   | 13.75 | 15.79 |
| Luanda   | Angola      | 8.58                        | 9.18    | 10.80 | 12.25 |
| Dar es Salaam | Tanzania | 9.27 | 10.67 | 11.67 | 12.71 |
| Karachi | Pakistan   | 11.30                       | 13.03   | 13.68 | 15.17 |
| Dhaka    | Bangladesh  | 9.65                        | 10.53   | 11.53 | 12.88 |
| Lahore  | Pakistan    | 9.75                        | 12.42   | 11.49 | 12.87 |
| Hyderabad | India     | 11.64                       | 12.36   | 12.95 | 15.99 |
| Bangalore | India     | 8.46                        | 9.88    | 10.29 | 12.58 |
| Chennai | India       | 14.93                       | 15.71   | 16.69 | 18.13 |
| Kolkata | India       | 11.47                       | 12.23   | 13.29 | 14.93 |
| Delhi    | India       | 10.10                       | 12.34   | 11.46 | 13.65 |
| Mumbai  | India       | 13.04                       | 14.14   | 14.99 | 16.65 |
| Baghdad | Iraq        | 4.44                        | 6.35    | 6.56  | 6.59  |
| Cairo   | Egypt       | 5.88                        | 7.71    | 8.55  | 8.80  |
| Manila | Philippines | 8.30                        | 10.42   | 11.11 | 12.30 |
| Jakarta | Indonesia   | 12.89                       | 13.18   | 13.84 | 15.02 |
| Shanghai | China      | 2.47                        | 2.90    | 2.95  | 3.81  |
| Beijing | China       | 3.13                        | 3.73    | 3.81  | 3.56  |
| Buenos Aires | Argentina | 2.00 | 2.30 | 2.38 | 2.55 |
| Rio De Janeiro | Brazil | 4.90 | 5.81 | 6.71 | 8.24 |
| Sao Paulo | Brazil     | 1.42                        | 2.05    | 2.57  | 3.80  |
Table s16 Projections of total minimum energy demand for basic cooling comfort under projected AC access in different scenarios for the selected megacities.

| City            | Country        | Energy demand for basic cooling comfort (PJ/yr) |
|-----------------|----------------|-----------------------------------------------|
|                 |                | 2010 1.5°C | 2050 SSP1 1.5°C | 2050 SSP2 1.5°C | 2050 SSP3 1.5°C | 2010 2.0°C | 2050 SSP1 2.0°C | 2050 SSP2 2.0°C | 2050 SSP3 2.0°C | 2010 3.0°C | 2050 SSP1 3.0°C | 2050 SSP2 3.0°C | 2050 SSP3 3.0°C |
| Kinshasa        | Congo DRC      | 0.05     | 1.36     | 1.51     | 1.85     | 0.49      | 0.54      | 0.66      | 0.25      | 0.28      | 0.34 |
| Lagos           | Nigeria        | 0.12     | 5.74     | 6.1      | 7.01     | 2.6       | 2.77      | 3.18      | 1.23      | 1.31      | 1.51 |
| Luanda          | Angola         | 0.14     | 2.82     | 3.32     | 3.77     | 0.99      | 1.17      | 1.33      | 0.57      | 0.67      | 0.77 |
| Dar es Salaam   | Tanzania       | 0.03     | 3.62     | 3.96     | 4.32     | 1.06      | 1.16      | 1.27      | 0.38      | 0.42      | 0.46 |
| Karachi         | Pakistan       | 0.52     | 8.17     | 8.58     | 9.52     | 3.08      | 3.23      | 3.59      | 1.05      | 1.1       | 1.22 |
| Dhaka           | Bangladesh     | 0.14     | 11.98    | 13.14    | 14.7     | 3.15      | 3.45      | 3.86      | 1.03      | 1.13      | 1.27 |
| Lahore          | Pakistan       | 0.26     | 4.16     | 3.85     | 4.32     | 1.43      | 1.32      | 1.49      | 0.48      | 0.45      | 0.5  |
| Hyderabad       | India          | 0.35     | 7.7      | 8.07     | 9.97     | 4.44      | 4.65      | 5.75      | 1.21      | 1.27      | 1.57 |
| Bangalore       | India          | 0.22     | 5.67     | 5.9      | 7.23     | 2.4       | 2.5       | 3.07      | 0.65      | 0.68      | 0.83 |
| Chennai         | India          | 0.49     | 11.09    | 11.78    | 12.8     | 7.14      | 7.59      | 8.24      | 1.7       | 1.81      | 1.97 |
| Kolkata         | India          | 0.84     | 17.9     | 19.44    | 21.84    | 11.58     | 12.59     | 14.15     | 2.91      | 3.17      | 3.56 |
| Delhi           | India          | 1.43     | 21.24    | 19.72    | 23.5     | 16.66     | 15.48     | 18.44     | 5.38      | 4.99      | 5.96 |
| Mumbai          | India          | 1.23     | 26.97    | 28.6     | 31.75    | 19.02     | 20.16     | 22.39     | 4.86      | 5.15      | 5.72 |
| Baghdad         | Iraq           | 0.35     | 2.7      | 2.81     | 2.81     | 1.72      | 1.78      | 1.79      | 1.51      | 1.57      | 1.57 |
| Cairo           | Egypt          | 0.27     | 8.23     | 9.12     | 9.38     | 7.47      | 8.28      | 8.52      | 4.24      | 4.73      | 4.88 |
| Manila          | Philippines    | 0.23     | 3.92     | 4.18     | 4.63     | 1.84      | 1.96      | 2.17      | 0.97      | 1.03      | 1.15 |
| Jakarta         | Indonesia      | 0.54     | 9.72     | 10.2     | 11.07    | 8.33      | 8.74      | 9.49      | 4.91      | 5.15      | 5.6  |
| Shanghai        | China          | 1.09     | 2.57     | 2.62     | 3.55     | 2.34      | 2.39      | 3.23      | 2.03      | 2.07      | 2.81 |
| Beijing         | China          | 1.94     | 4.15     | 4.28     | 3.92     | 3.78      | 3.91      | 3.58      | 3.37      | 3.48      | 3.19 |
| Buenos Aires    | Argentina      | 0.51     | 1.24     | 1.29     | 1.41     | 1.37      | 1.45      | 1.56      | 1.55      | 1.61      | 1.76 |
| Rio De Janeiro  | Brazil         | 1.34     | 3.4      | 3.96     | 4.89     | 3.59      | 4.14      | 5.09      | 3.73      | 4.34      | 5.32 |
| Sao Paulo       | Brazil         | 0.49     | 1.71     | 2.22     | 3.43     | 1.84      | 2.39      | 3.69      | 1.72      | 2.23      | 3.45 |
Table s17 Minimum energy requirements for universal access to basic cooling comfort in different scenarios for the selected megacities.

| City       | Country        | 2010 | 2050 SSP1 | 2050 SSP2 | 2050 SSP3 |
|------------|----------------|------|-----------|-----------|-----------|
|            |                | 1.5°C| 2.0°C     | 3.0°C     | 1.5°C     | 2.0°C     | 3.0°C     | 1.5°C     | 2.0°C     | 3.0°C     |
| Kinshasa   | Congo DRC     | 2.68 | 12.15     | 13.45     | 16.4      | 11.77     | 13.03     | 15.88     | 9.27      | 10.26     | 12.51     |
| Lagos      | Nigeria       | 4.85 | 17.36     | 18.46     | 21.2      | 18.39     | 19.54     | 22.44     | 19.01     | 20.2      | 23.2      |
| Luanda     | Angola        | 1.59 | 6.06      | 7.13      | 8.09      | 6.76      | 7.96      | 9.02      | 7.97      | 9.38      | 10.64     |
| Dar es Salaam | Tanzania  | 1.19 | 7.87      | 8.6       | 9.37      | 7.9       | 8.63      | 9.4       | 6.81      | 7.45      | 8.11      |
| Karachi    | Pakistan      | 5.4  | 18.76     | 19.7      | 21.85     | 17.64     | 18.52     | 20.54     | 15.25     | 16.01     | 17.76     |
| Dhaka      | Bangladesh    | 5.36 | 17.38     | 19.04     | 21.27     | 14.82     | 16.23     | 18.13     | 12.58     | 13.78     | 15.4      |
| Lahore     | Pakistan      | 2.53 | 9.71      | 8.99      | 10.07     | 9.13      | 8.45      | 9.47      | 7.89      | 7.3       | 8.18      |
| Hyderabad  | India         | 2.98 | 8.56      | 8.97      | 11.07     | 7.47      | 7.83      | 9.67      | 5.88      | 6.16      | 7.61      |
| Bangalore  | India         | 2.32 | 7.32      | 7.62      | 9.31      | 6.39      | 6.65      | 8.13      | 5.03      | 5.24      | 6.4       |
| Chennai    | India         | 4.27 | 12.17     | 12.92     | 14.04     | 10.62     | 11.28     | 12.26     | 8.36      | 8.88      | 9.65      |
| Kolkata    | India         | 6.77 | 19.52     | 21.2      | 23.82     | 17.04     | 18.51     | 20.8      | 13.42     | 14.57     | 16.37     |
| Delhi      | India         | 6.51 | 21.51     | 19.98     | 23.8      | 18.78     | 17.44     | 20.78     | 14.79     | 13.73     | 16.36     |
| Mumbai     | India         | 9.91 | 29.07     | 30.83     | 34.23     | 25.38     | 26.92     | 29.88     | 19.98     | 21.19     | 23.53     |
| Baghdad    | Iraq          | 0.95 | 3.27      | 3.38      | 3.4       | 3.55      | 3.66      | 3.68      | 3.58      | 3.7       | 3.71      |
| Cairo      | Egypt         | 2.84 | 8.58      | 9.51      | 9.79      | 8.3       | 9.19      | 9.47      | 6.86      | 7.6       | 7.83      |
| Manila     | Philippines   | 3.78 | 10.51     | 11.2      | 12.4      | 10.31     | 10.99     | 12.17     | 10.32     | 11        | 12.18     |
| Jakarta    | Indonesia     | 4.89 | 9.9       | 10.39     | 11.28     | 9.3       | 9.76      | 10.59     | 8.03      | 8.43      | 9.15      |
| Shanghai   | China         | 1.65 | 2.96      | 3.02      | 3.89      | 2.7       | 2.75      | 3.55      | 2.42      | 2.47      | 3.18      |
| Beijing    | China         | 2.6  | 4.74      | 4.83      | 4.51      | 4.32      | 4.41      | 4.12      | 3.87      | 3.95      | 3.69      |
| Buenos Aires | Argentina | 1.11 | 1.6       | 1.66      | 1.77      | 1.83      | 1.96      | 2.03      | 2.1       | 2.25      | 2.25      |
| Rio De Janeiro | Brazil   | 2.46 | 3.47      | 4.01      | 4.92      | 3.77      | 4.36      | 5.35      | 4.28      | 4.94      | 6.07      |
| Sao Paulo  | Brazil        | 1.15 | 1.97      | 2.47      | 3.65      | 2.14      | 2.68      | 3.97      | 2.43      | 3.05      | 4.5       |
**Table s18 Cities with the highest minimum energy requirements for universal access to cooling in 2050 under different SSPs and 2.0°C climate.**

| City     | 2050 – SSP1 Energy requirements (PJ/yr) | 2050 – SSP2 Energy requirements (PJ/yr) | 2050 – SSP3 Energy requirements (PJ/yr) |
|----------|----------------------------------------|----------------------------------------|----------------------------------------|
| 1. Mumbai| 30.8                                    | 26.9                                   | 21.1                                   |
| 2. Kolkata| 21.2                                    | 19.5                                   | 20.2                                   |
| 3. Dehli | 20.0                                    | 18.5                                   | 16.0                                   |
| 4. Karachi| 19.7                                    | 18.5                                   | 14.6                                   |
| 5. Dhaka | 19.0                                    | 17.4                                   | 13.8                                   |

Thermal comfort thresholds and cooling behavior of households are characterized by large uncertainties (Mastrucci et al. 2019; Khosla et al. 2021), that can substantially affect cooling requirements across different regions. Figure s4 shows the results of the sensitivity analysis of cooling energy intensity to main behavior-related model input drivers, including variation of indoor set point temperatures by ±2°C and doubling the number of hours of operation of cooling systems. Similar to previous studies (Mastrucci et al. 2019), the results show a high level of uncertainty related to both set point temperatures and hours of cooling operation. The effect of varying other activity-related parameter, such as per-capita floorspace and share of cooled floorspace, is similar to varying the number of hours of cooling operation, and therefore not shown.
Figure s4 Results of the sensitivity analysis of energy intensity for basic cooling to the main model input drivers. Whiskers indicate the effect of varying the indoor set point temperature by ±2°C. The symbols “x” indicate energy intensities after doubling the number of hours of cooling operation.
Bibliography

Dellink R, Chateau J, Lanzi E, Magne B (2017) Long-term economic growth projections in the Shared Socioeconomic Pathways. Glob Environ Chang 42:200–214. https://doi.org/10.1016/j.gloenvcha.2015.06.004

Hoornweg D, Pope K (2017) Population predictions for the world’s largest cities in the 21st century. Environ Urban 29:195–216. https://doi.org/10.1177/0956247816663557

Hu S, Yan D, Qian M (2019) Using bottom-up model to analyze cooling energy consumption in China’s urban residential building. Energy Build 202:. https://doi.org/10.1016/j.enbuild.2019.109352

Huppmann D, Gidden M, Fricko O, et al (2019) The MESSAGE ix Integrated Assessment Model and the ix modeling platform (ixmp): An open framework for integrated and cross-cutting analysis of energy, climate, the environment, and sustainable development. Environ Model Softw 112:143–156. https://doi.org/10.1016/j.envsoft.2018.11.012

IEA (2018) The Future of cooling. Opportunities for energy-efficient air conditioning. 90. https://doi.org/10.1016/S0181-5512(07)79285-9

Isaac M, van Vuuren DP (2009) Modeling global residential sector energy demand for heating and air conditioning in the context of climate change. Energy Policy 37:507–521. https://doi.org/10.1016/j.enpol.2008.09.051

Khosla R, Agarwal A, Sircar N, Chatterjee D (2021) The what, why, and how of changing cooling energy consumption in India’s urban households. Environ Res Lett 16:. https://doi.org/10.1088/1748-9326/abecbc

Kikstra JS, Mastrucci A, Min J, et al (2021) Decent living gaps and energy needs around the world. Environ Res Lett 16:. https://doi.org/https://doi.org/10.1088/1748-9326/ac1c27

Mastrucci A, Byers E, Pachauri S, Rao ND (2019) Improving the SDG energy poverty targets: Residential cooling needs in the Global South. Energy Build 186:405–415. https://doi.org/10.1016/j.enbuild.2019.01.015

Mastrucci A, van Ruijven B, Poblete-Cazenave M, et al (2021) Global scenarios of residential
heating and cooling energy demand. Clim Change 168:
https://doi.org/https://doi.org/10.1007/s10584-021-03229-3

McNeil M a., Letschert VE (2008) Future air conditioning energy consumption in developing countries and what can be done about it: the potential of efficiency in the residential sector

Murakami D, Yamagata Y (2019) Estimation of Gridded Population and GDP Scenarios with Spatially Explicit Statistical Downscaling. Sustainability 11:1–18.
https://doi.org/10.3390/su11072106

Pavanello F, De Cian E, Davide M, et al (2021) Air-conditioning and the adaptation cooling deficit in emerging economies. Nat Commun 12:. https://doi.org/10.1038/s41467-021-26592-2

Peel MC, Finlayson BL, McMahon TA (2007) Updated world map of the Köppen-Geiger climate classification. Hydrol Earth Syst Sci 11:1633–1644. https://doi.org/10.5194/hess-11-1633-2007

Rao ND, Min J (2017) Decent Living Standards: Material Prerequisites for Human Wellbeing. Soc Indic Res 138:225–244. https://doi.org/10.1007/s11205-017-1650-0

Riahi K, Vuuren DP Van, Kriegler E, et al (2017) The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. 42:153–168. https://doi.org/10.1016/j.gloenvcha.2016.05.009

Surahman U, Kubota T (2018) Chapter 32 Household Energy Consumption and CO2 Emissions for Residential Buildings in Jakarta and Bandung of Indonesia. In: Sustainable Houses and Living in the Hot-Humid Climates of Asia. Springer Nature Singapore Pte Ltd., pp 325–333

United Nations (2019) Household Size & Composition Last accessed March 2022.
https://www.un.org/development/desa/pd/data/household-size-and-composition