CLIMATE CENTRAL

Analysis: Climate change is increasing dangerous nighttime temperatures across the globe

August 8, 2024

Key Facts

- **Climate change** — caused by burning fossil fuels like oil, coal, and gas — is **causing a significant increase in dangerously hot nights across the globe**.
- Due to human-caused climate change, **2.4 billion people experienced an average of at least 2 additional weeks per year where nighttime temperatures exceeded 25°C**. Over 1 billion people experienced an average of at least 2 additional weeks per year of nights above 20°C and 18°C.
- **High nighttime temperatures are detrimental to human health**. These temperatures prevent the body from recovering from daytime heat, increase the risk of illness and mortality, and disrupt sleep. Short and poor quality sleep has a range of negative impacts on physical and mental health, cognitive function, and life expectancy.

Data

➢ **Download data** for 25 world regions, 202 countries and territories, and 994 cities
➢ **Download data** for states/provinces in the United States, Canada, and Brazil

INTRODUCTION

Nighttime temperatures have increased even more rapidly than daytime temperatures as the world heats up, exposing millions to potential health risks.

June 2024 was the thirteenth consecutive month to be the hottest on record, rising to 1.6°C above pre-industrial levels, following eleven months in a row during which global temperatures were at 1.5°C above pre-industrial levels. There are ongoing record-breaking heat waves around the world, which are being made more extreme and more likely by climate change. The primary cause of this warming is rising levels of carbon dioxide in the atmosphere from burning coal, oil, and natural gas.

High nighttime temperatures are particularly dangerous as they prevent the body from cooling down and recovering from daytime heat. This increases the risk of strokes, other cardiovascular conditions, and mortality, with scientific evidence that the relative mortality risk on days with hot nights could be 50 percent higher than on days with non-hot nights. Hot nights cause physiological discomfort, degrading the quality and length of sleep worldwide. Short and poor quality sleep has a wide range of negative physical and mental health impacts, including impaired immune function, adverse cardiovascular outcomes, cancer risks, diabetes, mental health conditions, suicidal behaviors, and shorter life expectancy. Poor sleep also negatively affects cognitive functioning, impairs children's brain development, learning and school performance, and increases the risks of accidents, injuries and safety-related deaths, including at work and while commuting.

Hot nights can have disproportionate impacts on more vulnerable groups, including infants, the elderly, and pregnant women. For example, sleep deprivation and disturbance in pregnant women have been linked to the increased risk of preterm birth, a variety of maternal health problems, postpartum depression, and adverse fetal outcomes. Moreover, the impacts of high nighttime temperatures vary between and within countries, with lower-income populations disproportionately affected, partly due to differences in the quality of housing and access to air conditioning.

The impact of hot nights can be exacerbated in cities due to heat island effects. Urban heat islands can increase temperatures in urban areas more than in surrounding areas. Heat island effects will continue to impact more and more people as the global population continues to rapidly urbanize, with almost 57 percent of the world living in cities in 2022 and a projected 68 percent by 2050.

The purpose of this analysis is to assess the extent to which human-caused climate change has increased the number of uncomfortably hot summer nights (December-February in the Southern Hemisphere, June-August in the Northern Hemisphere). To do this, we calculated the number of days where the nighttime minimum temperature exceeded 18°C, 20°C, and 25°C. We also used

the Climate Shift Index daily attribution system to quantify how climate change has influenced the number of uncomfortably hot nights. The Climate Shift Index uses observed patterns of warming and 24 global climate models to estimate the nighttime temperature that would have occurred in a counterfactual climate without human-caused climate change. The difference between the observed number and the counterfactual number gives the number of uncomfortable nights added by climate change. For this analysis, we focus on the annual average over the last 10 years (2014-2023) in countries, regions, and cities around the world.

This analysis is an update on the recent Climate Central report, *Sleepless Nights*, which focuses on how climate change has driven up nighttime temperatures in India, the U.S., and the U.K. The current report provides a detailed global analysis, examining the impacts of heat at night on regions, countries, and cities across the globe.

The analysis was carried out using three temperature thresholds.

18°C: There is evidence that sleeping at or around this temperature is optimal for sleep length and quality. The Sleep Charity in the U.K. defines the ideal room temperature for sleep as 16°C to 18°C. Egton Medical Information Systems Group (EMIS) in the U.K. suggests that the most comfortable bedroom temperature ranges between 15.5°C and 20°C, with temperatures above this associated with restlessness.

20°C: The Expert Team on Climate Change Detection and Indices (ETCCDI) defines tropical nights as when the daily minimum temperature exceeds 20°C. This threshold has been used by various meteorological agencies in Europe (including Spain, France, Switzerland, Germany, Ireland, U.K.). Additionally, the European Environment Agency's "Tropical Nights index" is defined as the annual number of days with a minimum night temperature of at least 20°C, causing physiological discomfort and impacting human health by preventing body temperature from cooling off during the night. In the U.S., the Centers for Disease Control and Prevention recommends keeping the room temperature between 18.3°C and 20°C (65ºF to 68ºF) at night and the National Sleep Foundation suggests between 15.6°C and 19.4°C (60ºF to 67ºF) is optimal.

25°C: This higher threshold accounts for countries with higher night-time temperatures. For example, tropical nights are defined as above 25°C in Japan. Other studies show that sleep quality seriously deteriorates above this threshold. A recent study provides "the first planetary-scale evidence that warmer-than-average temperatures erode human sleep", and shows that nighttime minimum temperatures greater than 25°C increase the probability of getting less than seven hours of sleep by 3.5 percentage points compared with the estimated optimum minimum nighttime temperature. The World Health Organization also recommends the room temperature be kept at 24°C during the night.

In some locations, the change in number of days above each temperature threshold due to climate change may be small or zero. This can occur if that location's temperature will never exceed one of the thresholds in both the counterfactual and observed scenario, or if it is always above that threshold in both scenarios.

RESULTS

1. Global

Just over 1.1 billion people on average experienced at least an additional 2 weeks each year where minimum temperatures exceeded 18°C due to human-caused climate change. Meanwhile, more than 305 million people on average experienced at least one additional month over this threshold.

On average, just over 1.3 billion people experienced at least an additional 2 weeks where nighttime temperatures exceeded 20°C. More than 390 million people experienced at least an additional 30 nights above 20°C.

Meanwhile, almost twice as many people experienced at least an additional 2 weeks above 25°C, with around 2.4 billion people per year on average living in places with changes of this magnitude. Just over 1 billion people on average experienced at least 30 additional days above 25°C due to climate change.

2. Regions

The region that experienced the greatest number of days with minimum temperatures above 18°C influenced by human-caused climate change is Southern Europe, with just over 2 weeks on average added each year. Regions were defined using ESRI Data and Maps, which defines boundaries for the 25 most commonly recognized regions.

- Eastern, Middle, and Southern Africa along with Eastern and Central Asia and Eastern and Western Europe experienced an additional 7 to 12 days above this threshold.
- Northern, Central, and South America, along with Western and Southern Asia and European Russia experienced between 3 and 6 additional days above 18°C added by climate change.
- Most summer nights in Northern and Western Africa, Melanesia, and Micronesia exceed 18°C in both the counterfactual and observed scenarios, so the average annual number of days added by human-induced climate change is low.

Climate change added over 2 weeks where nighttime temperatures in summer exceeded 20°C in Southern and Middle Africa.

- Most of Asia, with the exception of Southern Asia, along with Central and South America, Polynesia, Southern Europe, and Eastern Africa experienced 7 to 14 more days each year on average above this threshold.
- 3 to 6 additional days were observed in Northern Africa, Eastern and Western Europe, Melanesia, Northern America, Southern Asia, and Australia/New Zealand.
- Other locations such as Southeastern Asia, Western Africa, and Micronesia experienced only minor changes each year because the temperature exceeded 20°C in both the counterfactual and observed scenarios most days in the summer.

Northern and Western Africa, Southeastern and Western Asia, and the Caribbean experienced the greatest number of days with minimum temperatures above 25°C on average.

- An additional one to two weeks above this threshold were observed in Micronesia, Polynesia, Melanesia, Australia/New Zealand, Southern Asia, and Central America.
- 1 to 6 additional days were observed in Eastern, Middle, and Southern Africa; Eastern and Central Asia; North and South America, and Southern Europe.

3. Countries

The analysis showed that 59 of the 202 countries and territories analyzed from 2014-2023 experienced an additional week per year with minimum temperatures above 18°C on average over the past 10 years due to human-caused climate change (Figure 1). Uganda and Zambia were the most impacted countries during this time, with an additional month where nighttime temperatures exceeded 18°C on average during the summer.

Climate change added between 15 and 26 days above this threshold in countries including:

- Tanzania, Angola, Rwanda, Burundi, and Namibia in Africa
- Spain, Italy, Croatia, Moldova, Bulgaria, Hungary, and Azerbaijan in Europe and Asia.

On average, 7 to 14 days additional days with minimum temperatures above 18°C were added by climate change in:

- France, Poland, Belarus, Slovakia, Slovenia, Kosovo, Albania, Portugal, Romania, Bosnia and Herzegovina, Ukraine, and Macedonia in Europe.
- Japan, Kazakhstan, Afghanistan, Uzbekistan, North Korea, South Korea, China, Mongolia, Armenia, and Nepal in Asia.

- Turkey, Iran, Syria, and Jordan in the Middle East
- South Africa, Kenya, Botswana, Ethiopia, Eswatini, Zimbabwe, Morocco, and the Democratic Republic of the Congo in Africa.
- Mexico, the United States, Ecuador, Guatemala, Uruguay, and Peru in North and South America.

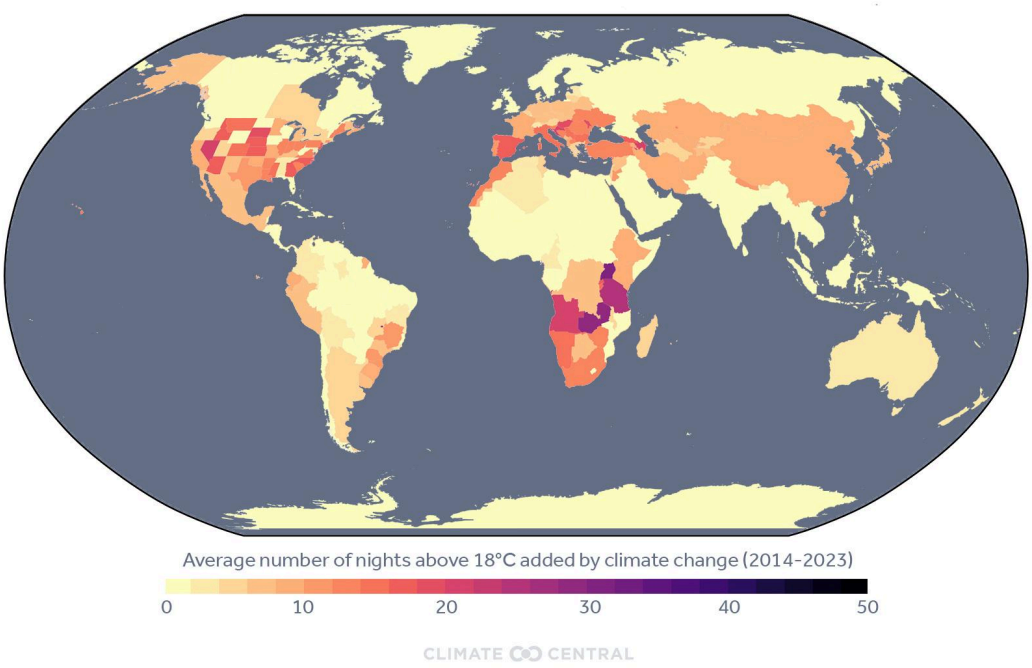

Figure 1. Average number of days with minimum nighttime temperatures above 18°C due to climate change. The warming rate is expressed as the annual change in days averaged over 2014-2023.

During this time, approximately 20 to 30 days with minimums above 20°C (Figure 2) were added by climate change in Jordan and Azerbaijan, as well as in several African countries including Cameroon, Uganda, Equatorial Guinea, Botswana, Zimbabwe, Zambia, Gabon, and Tanzania.

Many other countries experienced an additional 10 to 20 days with nighttime temperatures above this threshold including Spain, Italy, Turkey, South Africa, Kenya, Morocco, Ecuador, Guatemala, and Honduras.

Other countries that experienced between 4 and 9 additional days where the temperature did not drop below 20°C include France, Cyprus, Greece, Romania, Hungary, Japan, South Korea, Australia, Argentina, Brazil, Venezuela, the United States, Libya and Egypt.

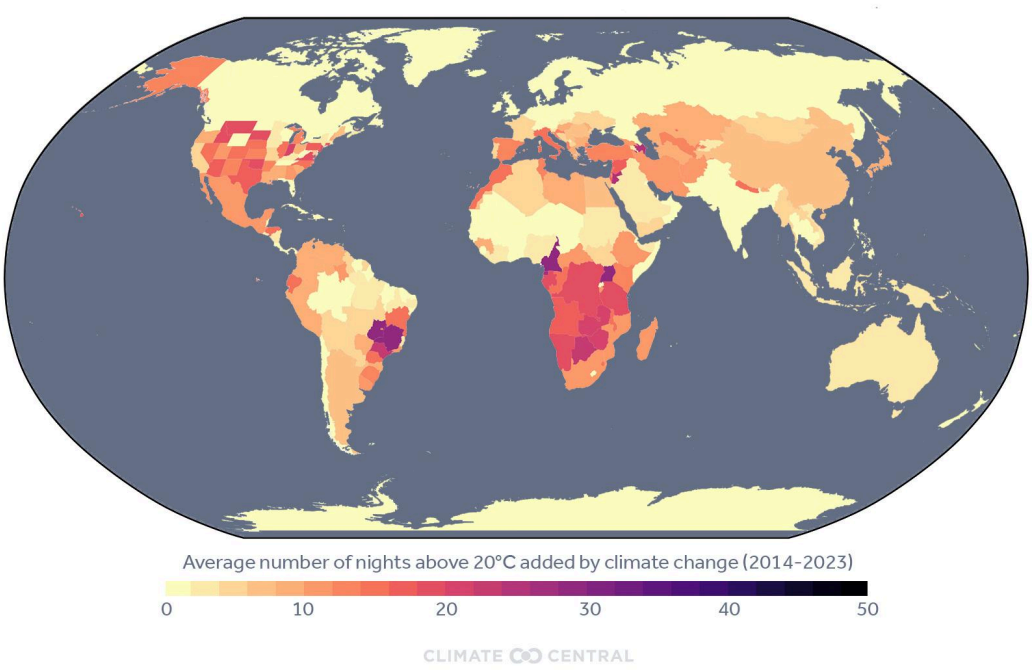

Figure 2. Average number of days with minimum nighttime temperatures above 20°C due to climate change. The warming rate is expressed as the annual change in days averaged over 2014-2023.

Large increases in the number of days where the nighttime temperature exceeded 25°C were observed globally (Figure 3). On average (from 2014-2023), 30 to 45 additional days above this threshold were observed in Trinidad and Tobago, Singapore, Brunei, Gambia, Cambodia, Thailand, Senegal, Niger, Guinea-Bissau, and French Polynesia.

An additional 20 to 30 days with minimums above 25°C were observed in several African and Middle Eastern countries, as well as in Southern and Southeastern Asia, Oceania, the Caribbean, and Europe, including: Bangladesh, Sri Lanka, Saudi Arabia, Libya, Algeria, Tunisia, Iraq, Egypt, Chad, Sudan, Vietnam, the Philippines, Jamaica, Samoa, Niue, Cyprus, Malta, etc.

Approximately 40 countries experienced 10 to 20 additional days with nighttime temperatures above this threshold due to climate change, including countries such as Australia, Papua New Guinea, Indonesia, Vanuatu, Comoros, Fiji, Myanmar, Pakistan, Afghanistan, Nigeria, Kenya, Mali, Ghana, Haiti, Costa Rica, Eritrea, Israel, Mexico, etc.

At least an additional week with minimum temperatures above 25°C was added by climate change in Japan, Morocco, Somalia, Mozambique, Madagascar, and Guatemala.

Other countries experienced between 3 and 6 additional nights above 25°C on average, including Brazil, Suriname, Bolivia, China, Malawi, Greece, and Azerbaijan.

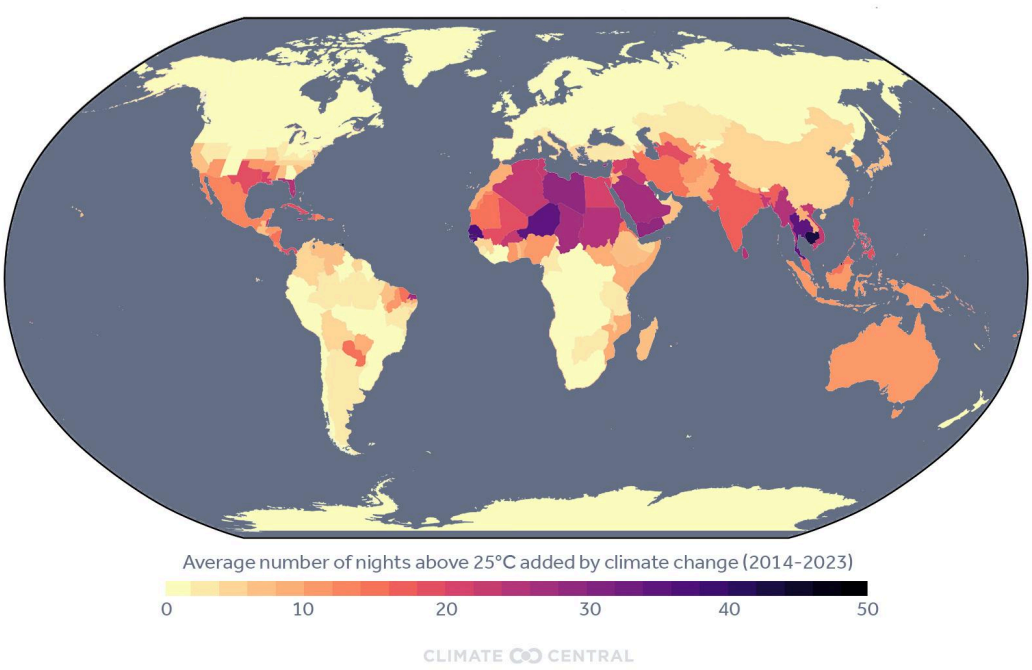

Figure 3. Average number of days with minimum nighttime temperatures above 25°C due to climate change. The warming rate is expressed as the annual change in days averaged over 2014-2023.

4. Cities

Of the 994 cities analyzed, 30 experienced at least an additional month added by climate change where the nighttime temperature during the summer was greater than 18°C. Of these cities, 8 observed an additional 2 months of days above 18°C. Kathmandu, Nepal observed an additional three months (89 additional days) above 18°C, meaning that without climate change, these nighttime temperatures would have been exceedingly rare.

Cities that experienced an additional month of minimum temperatures above 18°C due to climate change include:

- Europe: Bucharest, Romania; Zagreb, Croatia; Madrid, Spain; and Turin and Milan, Italy
- Asia: Kathmandu, Nepal; Yerevan, Armenia; Kermanshah and Karaj, Iran; Baoshan, Dali, Dadukou, Urumqi, Yuxi, Lincang, Kunming, and Yucheng, China
- South America: Brasilia, Brazil; Lima and Trujillo, Peru; and Palermo and Cali, Colombia in South America
- North America: Albuquerque and Salt Lake City, United States; Chihuahua, Zapopan, and Guadalajara, Mexico
- Africa: Lubumbashi, Congo; Marrakech, Morocco

Several other cities experienced an additional 10 to 30 nights above this threshold due to climate change, including (but not limited to):

- Sydney, Perth, and Adelaide in Australia; and Auckland, New Zealand in Oceania
- Belo Horizonte, Goiana, and Porto Alegre in Brazil
- Cape Town, Durban, Pietermaritzburg, and Johannesburg in South Africa
- Toronto, Ottawa, Montreal, and Winnipeg in Canada

Other cities across Brazil, Indonesia, as well as the majority of cities in Africa, and the Middle East, observed smaller annual average increases in days where nighttime temperatures exceeded 18°C because these temperatures were common in both the counterfactual and observed scenarios.

Forty three cities globally experienced at least an additional month where minimum temperatures were above 20°C due to human-caused climate change. Bujumbura, Burundi and Barinas, Venezuela experienced an additional 85 and 90 nights above this threshold on average. Monterrey, Mexico experienced an additional 65 nights where the minimum temperature exceeded 20°C.

Other cities that experienced annual increases between 30 and 60 days include (but are not limited to):

- Kampala, Uganda; Kaduna, Nigeria; Mbuji-Mayi and Kananga, Congo; and Yaounde, Cameroon
- Goiana and Campinas, Brazil; Lima, Peru
- Valencia and Barcelona, Spain; Milan, Turin, and Rome, Italy; Marseille, France

Several cities in China, India, Mexico, New Zealand, and several cities in Middle Eastern and African countries also experienced at least 10 days above 20°C added by climate change.

Larger changes were observed in cities for the number of days that climate change added above 25°C, with 136 cities experiencing at least one additional month where minimum temperatures stayed above this threshold. Guwahati, India and Cilacap, Indonesia were the most affected cities, with an additional 85 to 86 days above 25°C on average.

Climate change added at least 60 days above this threshold in 18 other cities including:

- Natal, Fortaleza, Maceió, and Salvador; Brazil
- Kalyan, Thane, and Mumbai; India
- Yangon, Myanmar
- Mersin, Turkey
- Padang and Surabaya, Indonesia

- Vientiane, Laos
- Mombasa, Kenya
- Bien Hoa, Vietnam
- Klang, Malaysia
- Culiacan and El Dorado, Mexico
- Conakry, Guinea

Across Asia, Africa, and the Middle East, 118 cities experienced between 30 and 60 more days with minimum temperatures above 25°C than they would have without climate change, including

- Lagos, Nigeria
- Dar es Salaam, Tanzania
- Freetown, Sierra Leone
- Luanda, Angola
- Islamabad, Pakistan
- Erbil, Iraq
- Hanoi and Ho Chi Minh City, Vietnam
- Taipei, Taiwan
- Osaka, Japan

Some cities in the United States, Mexico, and Central and South America also observed changes of this magnitude, including Maracaibo, Venezuela; Sao Luis, Brazil; Managua, Nicaragua; Villahermosa, Mexico; Tampa, Phoenix, and New Orleans, United States.

Climate change added between 10 and 30 days on average above 25°C in 335 cities globally. Asian cities accounted for 277 of those 335 cities, with a majority of those cities in China.

Other cities that experienced an additional 10 to 30 days include (but are not limited to):

- Algiers, Algeria
- Ouagadougou and Bobo-Dioulasso, Burkina Faso
- Giza and Cairo, Egypt
- Accra and Tamale, Ghana
- Bamako, Mali
- Maputo, Mozambique
- Kano, Nigeria
- Mogadishu, Somalia
- Colombo, Sri Lanka
- Recife, Rio de Janeiro, Teresina, Sao Goncalo, Santos, Belem, and João Pessoa; Brazil
- Cartagena, Cucuta, and Barranquilla, Colômbia
- Naples, Italy

- Oklahoma City, Memphis, Jacksonville, El Paso, Virginia Beach, Las Vegas, Miami, Austin, Dallas, Fort Worth, and Houston, United States

METHODS

Calculating days above uncomfortable temperature thresholds
An analysis of observed global temperature patterns was done using ERA5 reanalysis temperature data. The data is available at a resolution of 0.25° (31 km). Additionally, the analysis utilized counterfactual temperatures or the temperature that would have occurred in a world without human-induced climate change. This is estimated using Climate Central's Climate Shift Index (CSI) system. The system uses the latest peer-reviewed attribution science, quantifying the influence of climate change on daily temperatures around the world.

We typically express this influence as a change in the likelihood of the observed temperature due to climate change. However, it is also possible to use the CSI system to estimate the temperature without climate change. To do this, we find the probability of exceeding the observed temperature in the modern climate. We then find the temperature with the same probability in a climate with no global warming (global mean temperature of 0° relative to the preindustrial period). We estimate these counterfactual temperatures using each of the observation and model-based methods in the CSI system and then average.

For the global analysis, we extracted the data corresponding to each hemisphere's summer season: June, July, and August for the Northern Hemisphere, and December, January, and February for the Southern Hemisphere. We then counted the number of days in each month where the minimum temperature exceeded 18°C, 20°C, and 25°C over the ERA5 and counterfactual temperatures from 2014-2023. We then summed the annual count for each year in both scenarios and found the difference to assess how climate change has impacted nighttime temperatures.

We spatially averaged the counts within each country, with larger countries such as Brazil, Canada, and the United States broken down into states/provinces to assess changes between the number of days above each threshold added by climate change. This analysis was repeated for global regions along with cities that have a population greater than 750,000 to achieve city-specific attributability counts.

Data on cumulative greenhouse gas emissions (1851-2021) by country are reported in Jones et al. (2023) and available for download, along with various country groupings as defined by the United Nations Framework Convention on Climate Change (UNFCCC) at: https://zenodo.org/record/7636699.

REPORT CONTRIBUTIONS

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