Studie

The Regional Climate Divide of Data Centers

Between Energy Transition and US-Rollback

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The Regional Climate Divide of Data Centers
Between Energy Transition and US-Rollback

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Foreword

The disruptive developments of Big Tech and artificial intelligence rightly dominate public discourse. This is not surprising. After all, many people fear not only the loss of their jobs but are increasingly concerned about the stability of democracy or even the future of humanity.

While these societal dangers and risks of the misuse of this new technology are increasingly being brought to the public's attention by both Greenpeace and other actors such as the Pope, other aspects – such as the enormous burden on people and the environment caused by the energy-intensive operation of data centers – are losing significance.

The pace of technological advancement is so rapid that adherence to planetary boundaries – such as limits on resource consumption – is increasingly being reinterpreted by industry representatives as an obstacle to progress. In particular, the societal desire to meet climate protection goals seems to be hindering the few beneficiaries on their path to greater market power and even larger monopoly profits.

This study therefore examines the potential impacts of the tech industry's insatiable appetite for resources on environmental goals such as the Paris Climate Agreement, and identifies the need for action within the industry. To this end, it analyzes the effective emissions intensity and absolute emissions from data center operations in different regions and among different data center operators, using granular, regional electricity mixes.

The study's findings speak for themselves: carbon footprints in different regions of the world are both a clear consequence of varying policies on decarbonizing the electricity supply and the result of the operators' own investment decisions. Ultimately, these operators decide where to locate their data centers and consciously accept that data centers in regions with particularly dirty electricity mixes have a worse footprint.

To counteract this deterioration, operators have only two options. They can build their data centers in regions with a clean electricity mix, or they can ensure that the operation of their data centers is secured through the expansion of renewables, from which they directly and verifiably source electricity. In addition, they must advocate for policies that accelerate decarbonization and ensure that these efforts are not undermined by climate-damaging lobbying.

Based on the study's findings, Greenpeace makes the following demands to data center operators and their customers to ensure compliance with climate targets.

Planetary boundaries must serve as a binding guardrail for the expansion of computing capacity. Specifically, this means:

- Data centers must be operated exclusively with verifiably 100 % additional renewable electricity—no new construction based on fossil fuel capacity.
- Global hyperscalers such as Amazon Web Services, as the industry's largest greenhouse gas emitter, bear a special responsibility and must fully and verifiably transition their global electricity consumption to renewables.
- As long as hyperscalers, particularly in the U. S., continue to operate climate-damaging capacities, they are ruled out as partners for a climate-friendly digital infrastructure in Europe.

The industry leader and, according to the calculations in this study, the largest emitter of greenhouse gases, Amazon Web Services (AWS), a wholly owned subsidiary of Amazon, bears a special responsibility. As long as AWS operates a global network of data centers with energy supplies that are, in some cases, highly harmful to the climate – thereby prioritizing its unscrupulous profit interests over the public good – the market leader cannot be a responsible business partner for sustainability-oriented customers.

Executive Summary

This study analyzes the global energy consumption and greenhouse gas emissions of data centers for the first time on a granular basis using regional electricity mixes. The analysis is based on a dataset of approximately 6,700 data centers (BloombergNEF), supplemented by regional emission factors from Ember Energy and the U. S. Environmental Protection Agency (EPA).

In 2025, data centers worldwide consumed at least 485 TWh of electricity – about 4 % of global electricity consumption and nearly as much as Germany's total electricity demand. More than half of this is accounted for by the U.S. alone (247 TWh), while Europe contributes 86 TWh (18 %).

Methodologically, the study adopts a deliberately realistic accounting approach: it abstracts both from the purchase of so-called green electricity via certificates (which is considered insufficient for a guaranteed clean electricity supply) and from direct on-site and grid-based electricity consumption, for which no reliable data is available due to a lack of transparency. Instead, the decisive factor is the actual emissions of the electricity that physically supplies the data centers via the grid. On this basis, global emissions for 2025 are estimated at a minimum of 170 million tons of CO2e – more than the entire German transportation sector – with a projected growth path of up to 529 million tons. This trend fundamentally contradicts the goals of the Paris Climate Agreement, which require a global reduction in emissions by around 40 % by 2030 compared to 2020.

Key findings:

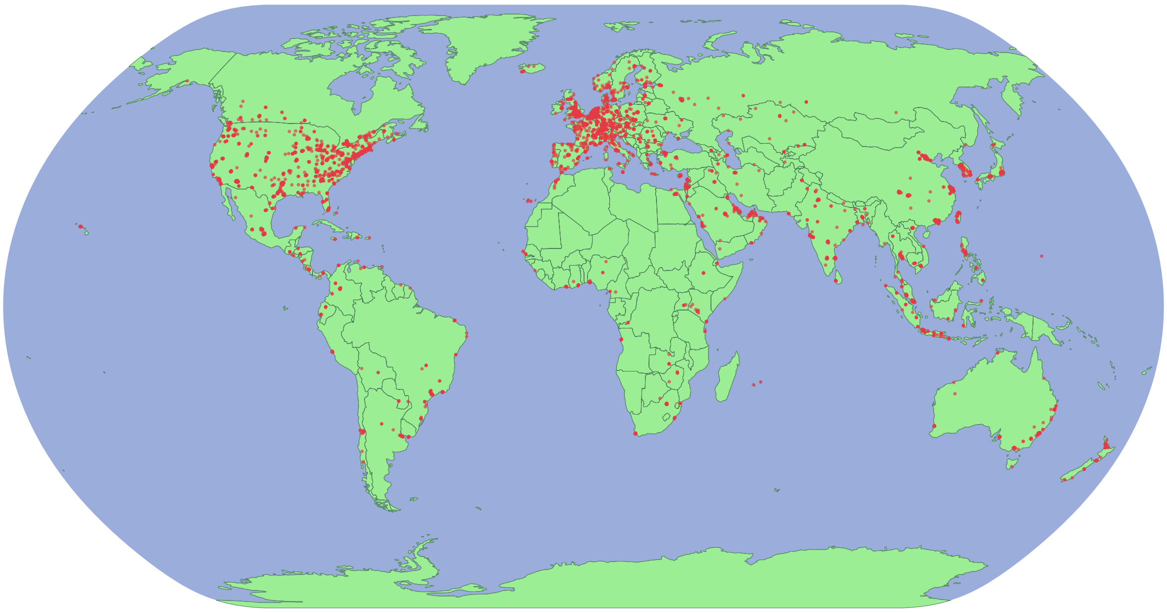
- **Europe computes cleaner.** Data center operations in Europe are significantly more climate-friendly than in other regions of the world, such as the U. S. or China. This is reflected in the carbon intensity of computing (CUE): The European average of 263 g CO_2e / kWhIT contrasts with significantly higher national figures, such as in the U.S. (414 g) or in carbon-intensive markets like China (695 g) and India (900 g).
- **Energy transition versus rollback.** Projections for planned expansion through 2030 reveal a mixed picture: In Europe and nearly worldwide, progress in the energy transition is improving the carbon footprints of data centers. In the U. S., however, the rollback in climate policy is taking its toll: here, carbon footprints are set to worsen by 2030. This trend is exacerbated by the construction of dedicated gas-fired power plants to supply data centers, driving CUE values up to 727 g COze / kWhIT.
- **Hyperscalers on par – European providers have the edge.** In terms of emissions intensity, there are no significant differences among the major commercial hyperscalers Amazon Web Services, Google Cloud, and Microsoft. Purely European providers, by contrast, perform better because they benefit from Europe's clean electricity supply.
- **Amazon Web Services is the largest single emitter.** In terms of absolute emissions, the inadequate carbon footprints of globally operating hyperscalers mean that they are responsible for by far the largest volume of emissions. Amazon Web Services stands out as the largest single greenhouse gas emitter, with approximately 14 million metric tons of CO_2e annually. In 2025, the four largest companies (Amazon Web Services, Meta, Google, Microsoft) together accounted for 45 % of global data center emissions – finding that makes the climate neutrality by 2030 pledged in the industry's »Climate Neutral Data Center Pact« appear unattainable.

Methodological caveat. All absolute values should be understood as lower bounds, as the dataset is estimated to cover only about half of the actual installed capacity, and providers treat their consumption data as trade secrets.

The Regional Climate Divide of Data Centers: Between Energy Transition and US-Rollback

Study commissioned by Greenpeace Germany

Berlin, June 8th, 2026



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Jens Gröger and Felix Behrens
Study commissioned by Greenpeace Germany.
Öko-Institut. Berlin. 2026.

The diagram on the previous page shows the locations of the data centres examined in this study.

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List of Abbreviations

Abbreviation	Full Form
AI	Artificial Intelligence
AWS	Amazon Web Services
BDEW	German Association of Energy and Water Industries
BNEF	Bloomberg New Energy Finance
CNDCP	Climate Neutral Data Centre Pact
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CPU	Central Processing Unit
CUE	Carbon Usage Effectiveness
DC	Data Centre
EF	Emission Factor
EnWG	German Energy Economy Act
EPA	United States Environmental Protection Agency
ERF	Energy Reuse Factor
g	gram
g CO_2 e/kWh_{IT}	Grams of carbon dioxide equivalent per kilowatt-hour of information technology
GCC	Gulf Cooperation Council (Members include: United Arab Emirates, Saudi Arabia, Qatar, Oman, Bahrain, Kuwait)
GW	Gigawatt
GWh	Gigawatt-hours (= 10^6 kilowatt-hours)
h/a	Hours per year
IEA	International Energy Agency
IT	Information Technology
kt	Thousand metric tons
kt CO_2 e/a	Thousand metric tons of carbon dioxide equivalents per year
kW	Kilowatt
kWh	Kilowatt-hour (= 10^3 watt-hours)
kWh_{el}	Kilowatt-hours (electric)
Mt	Million metric tons
Mt CO_2e/a	Million metric tons of carbon dioxide equivalents per year
MW	Megawatts
MWh	Megawatt-hour (= 10^3 kilowatt-hours)
MWh_{el}	Megawatt-hours (electric)
MWh_{IT}	Megawatt-hours for information technology
PPA	Power Purchase Agreement
PUE	Power Usage Effectiveness
RWUE	Radioactive Waste Usage Effectiveness
TWh	Terawatt-hours (= 10^9 kilowatt-hours)
USA	United States of America

Summary

This study analyses global energy consumption and greenhouse gas emissions from data centers, based on a database of approximately 6,700 data centers worldwide. According to the findings, data centers consumed at least 485 TWh of electricity globally in 2025 – roughly 4% of global electricity consumption and comparable in scale to Germany's entire electricity demand. More than 50% of this consumption is attributable to the USA (247 TWh), whilst Europe contributes 86 TWh (18%). Within Europe, the United Kingdom leads (14 TWh), followed by Germany (11 TWh), Ireland (10 TWh) and the Netherlands (9 TWh). In Germany, the Greater Frankfurt area dominates with approximately 7 TWh per year, making it by far the largest data center location, ahead of Berlin (0.8 TWh) and Munich (0.6 TWh).

Under the “Climate Neutral Data Centre Pact”, leading technology companies have committed to achieving climate neutrality by 2030. The study takes a critical view of this pledge: renewable energy certificates (PPAs) purchased without a physical grid connection to the data center result, in practice, in coal and gas power plants filling supply gaps. Actual global greenhouse gas emissions from data centers stood at a minimum of 170 million metric tons of CO_2e in 2025 – with a growth trajectory pointing towards as much as 529 million metric tons. The four largest technology companies (Amazon Web Services, Meta, Google and Microsoft) were jointly responsible for 45% of global greenhouse gas emissions from all data centers in 2025, placing them far from operating in a climate-neutral manner.

The metric CUE (Carbon Usage Effectiveness) is employed in this study to describe the climate relevance of a data center location. The value depends on the local electricity mix and the building efficiency (Power Usage Efffectiveness – PUE). The global range of CUE values is considerable: countries with carbon-intensive electricity mixes such as India (900 g CO_2e/kWh_{IT}), Australia (698), China (695) and Japan (630) are significantly higher than Europe's average of 263 g. Germany sits at 430 g and the USA at a national average of 414 g – though individual US states exceed this figure by a notable margin. The current trend in the USA of installing dedicated gas-fired power plants to operate data centers results in even higher CUE values of up to 727 g CO_2e/kWh_{IT}.

This study also introduces the metric RWUE (Radioactive Waste Usage Effectiveness), which indicates how much highly radioactive waste is generated per unit of computing work through the use of nuclear power. Particularly high values are recorded in regions with a large share of nuclear generation, such as France at 2.5 g/MWh_{IT} or certain US states with values of up to 2.1 g/MWh_{IT}. A 100 MW data center in France thereby generates approximately 1.5 metric tons of highly radioactive waste annually. The growing use of nuclear power by technology companies – sometimes explicitly declared as "climate-neutral" – thus shifts the environmental burden onto a long-term waste disposal problem.

This study identifies several effective levers for reducing greenhouse gas emissions from data centers. First, the choice of location plays a decisive role: data centers situated in regions with a high proportion of renewable energy benefit from lower emission factors. This advantage can also be achieved through investment in dedicated photovoltaic or wind energy installations, provided these are physically connected. Second, the utilization of waste heat can improve the carbon footprint by substituting fossil-fuel-based heat generation. Third, the intermediate storage of solar and wind power in battery systems enables a more temporally flexible use of renewable energy and contributes to reducing CUE values.

Notes on the analyzed data

For this study, the proprietary dataset "Data center projects database 1.4.0" from the consulting firm Bloomberg New Energy Finance (BloombergNEF 2026) was analyzed and combined with additional freely available data sources. The BNEF data provides an overview of data centers planned and in operation worldwide, including their respective owners, locations, installed load, operating concepts, commissioning dates, and other data. Of the approximately 6,700 data centers listed there, 420 were undergoing capacity expansion and 426 were still in the construction phase at the time of the survey. To conduct the analyses, this data was supplemented with key figures from the non-profit think tank EMBER (Ember-Energy 2026) and the U.S. Environmental Protection Agency (EPA 2025) regarding local electricity generation and shares of nuclear energy, as well as the Öko-Institut's own assumptions regarding future developments.

Since the BNEF database includes only known and publicly searchable data centers, it naturally represents only a subset of the data centers actually in operation. It can be assumed that many corporate data centers, cryptocurrency data centers, and military or government-run data centers are not included in the dataset. For Germany, for example, based on the energy consumption of 11 TWh in 2025 calculated in this study – as opposed to the figure of 22 TWh from the German Federal Ministry for Economic Affairs (Murzakulova 2025) – we assume that only about 50% of installations are accounted for. The absolute figures for electricity consumption and greenhouse gas emissions presented here therefore represent only a subset of global electricity consumption and emission levels.

In its latest publication on global energy consumption by data centers, "Key Questions on Energy and AI" (IEA 2026) , the International Energy Agency has calculated the figures 485 TWh for 2025 and 950 TWh for 2030 (forecast). These figures also represent the lower bounds of global energy consumption by data centers, as they were derived using a bottom-up method, just as in the present study. In the previous study by the Öko-Institut for Greenpeace (Gröger et al. 2025), a top-down approach was chosen to estimate global electricity consumption by data centers. The two projected figures for 2025 and 2030 were 651 and 1,389 TWh, respectively, which is up to 46% higher than the current IEA figures.

Nevertheless, we have decided to use the more recent figures of the IEA (2026) to scale the energy consumption figures from the BNEF data. The analysis presented here is therefore on the same order of magnitude as the IEA data. Here, too, actual consumption and emissions are likely to be higher in reality. Since there are still no reliable statistics on data center energy consumption and providers classify this information as trade secrets, the figures cannot be conclusively verified.

1 Background

Large parts of the data center industry and digital service providers have committed to becoming climate-neutral by 2030 through the “Climate Neutral Data Centre Pact” (CNDCP 2025). Co-signatories of this initiative include the major technology corporations Amazon Web Services (AWS), Meta, Google, and Microsoft, as well as approximately 100 other operators of data centers and colocation services. This voluntary commitment is intended to demonstrate that companies are willing to contribute to climate protection and that additional legal requirements for technology companies are unnecessary.

The announced climate neutrality is achieved, in theory, by purchasing electricity from renewable energy sources via so-called *power purchase agreements* (PPAs) – that is, agreements to purchase low-emission electricity from elsewhere. However, these supply agreements have dubious benefits for climate protection. For the following reasons, there is cause for concern that this amounts to nothing more than *greenwashing* – that is, an environmental claim that does not result in any real environmental benefits:

First, the purchased renewable electricity generally cannot be transmitted to the data center because the necessary transmission line capacity is lacking or because the electricity is generated on another continent. Second, the electricity is not produced at the same time the data center consumes it. This is because electricity generation from solar and wind power fluctuates daily and seasonally, while data centers typically operate around the clock with a nearly constant load. As a result, gas and coal-fired power plants connected to the data centers via power lines step in to fill the electricity gap, causing rising greenhouse gas emissions.

Another option for technology companies is to purchase nuclear power to operate their data centers, which is also declared “carbon-neutral” under the “Climate Neutral Data Center Pact.” The consequences of this are the more intensive or prolonged operation of nuclear power plants and an increased volume of highly radioactive waste, with the associated risks and costs for society.

In this study, we conduct a realistic assessment of greenhouse gas emissions from data centers and technology companies. In reality, data centers are physically connected to power plants via power grids and cause actual emissions there.

Therefore, this study does not take into consideration *power purchase agreements* that lack a physical connection to the data centers. Supply agreements that exist only on paper and that redirect only cash flows but not electricity flows are not taken into account. Instead, the greenhouse gas emissions from electricity generation in the respective regions of the data centers are used for the calculation.

This more realistic accounting method demonstrates how greenhouse gas emissions from data centers are actually evolving and why the climate neutrality announced in the “Climate Neutral Data Centre Pact” cannot be achieved with the current strategies of technology companies.

2 Regional distribution of data centers

2.1 Energy consumption

The available data specifies the electrical connected load of the IT equipment per data center. This parameter is generally used to describe the size of a data center. To calculate annual energy consumption, both the additional losses in building services (particularly cooling systems and power supply) and the utilization rate of the data centers must be taken into account.

2.1.1 Key metric for losses in building services: Power Usage Effectiveness

Losses in building services are described according to the EN 50600-4-2 standard by the *Power Usage Effectiveness* (PUE):

$$PUE = \frac{(electricity\ consumption\ of\ the\ entire\ data\ center)[kWh/a]}{electricity\ consumption\ of\ IT\ \ [kWh/a]} \quad [\text{no unit}]$$

To calculate the losses, this study used either the PUE values individually specified in the database for the respective data centers or, in cases of missing data, an average PUE value between 1.31 and 1.4 depending on the data center's operational concept. For the utilization of the data centers, an average CPU utilization of 33% is assumed, which results in an average electrical utilization of the IT systems of 67% (see *load factor* in IEA 2026). The annual electricity consumption of the data centers is then calculated as follows:

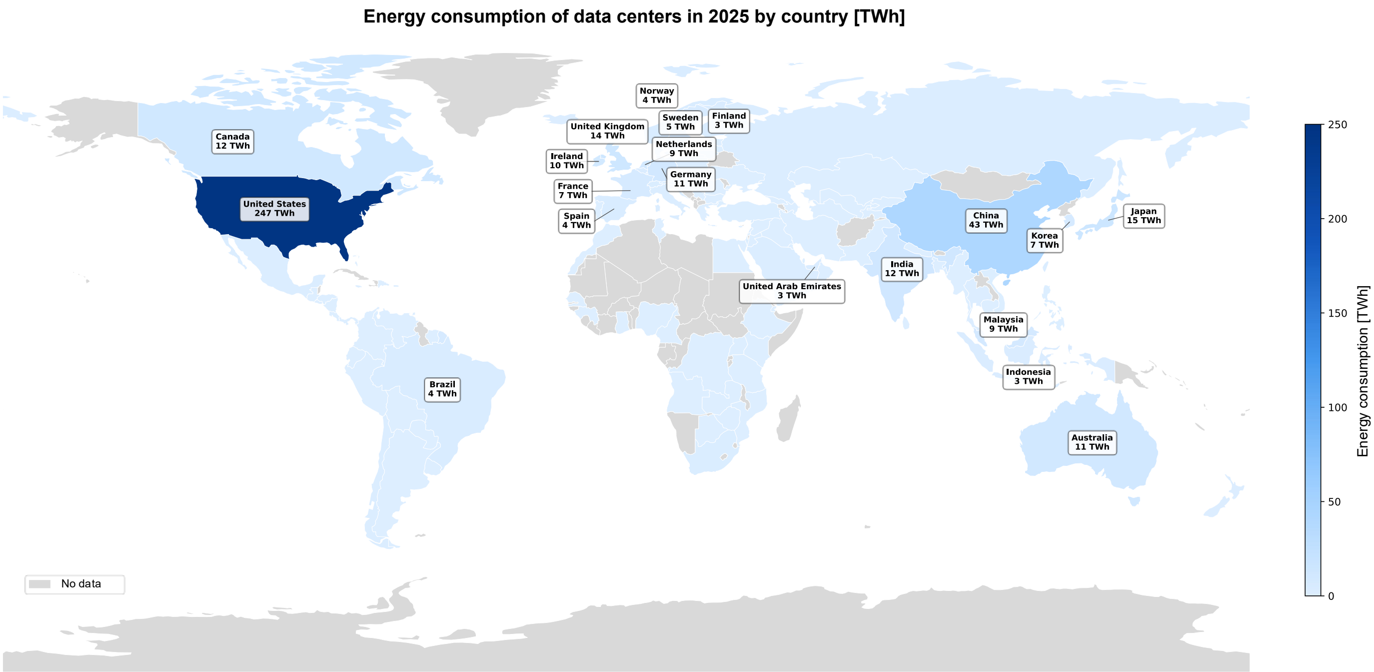
$$Electricity\ consumption\ DC = installed\ \ IT\ load\ [kW] \cdot PUE \cdot 67\% \cdot 8760\ h/a \qquad [\text{kWh/a}]$$

2.1.2 Energy Consumption World Map

In 2025, data centers worldwide consumed at least 485 terawatt-hours (TWh) of electricity. This is on the same order of magnitude as the amount of electricity consumed in Germany and accounts for approximately 4% of global electricity consumption (Enerdata 2025).

However, the regional distribution of this electricity consumption varies greatly. At 247 TWh, more than 50% of the electricity is consumed by data centers in the United States of America. China consumes 43 TWh, accounting for 9% of global data center electricity consumption. Japan (15 TWh), the United Kingdom (14 TWh), India (12 TWh), Canada (12 TWh), Australia (11 TWh), Germany (11 TWh), Ireland (10 TWh), and the Netherlands (9 TWh) make up the rest of the 10 largest consumers. The following world map (Figure 2-1) provides an overview of the global distribution. In addition to color coding, the 20 countries with the highest consumption volumes are labeled with numerical values. As described in the info box "Notes on the analyzed data", the figures refer only to the data centers listed in the BloombergNEF database. No data is available for some regions as well as data centers that are subject to confidentiality.

Figure 2-1: Global data center energy consumption in 2025

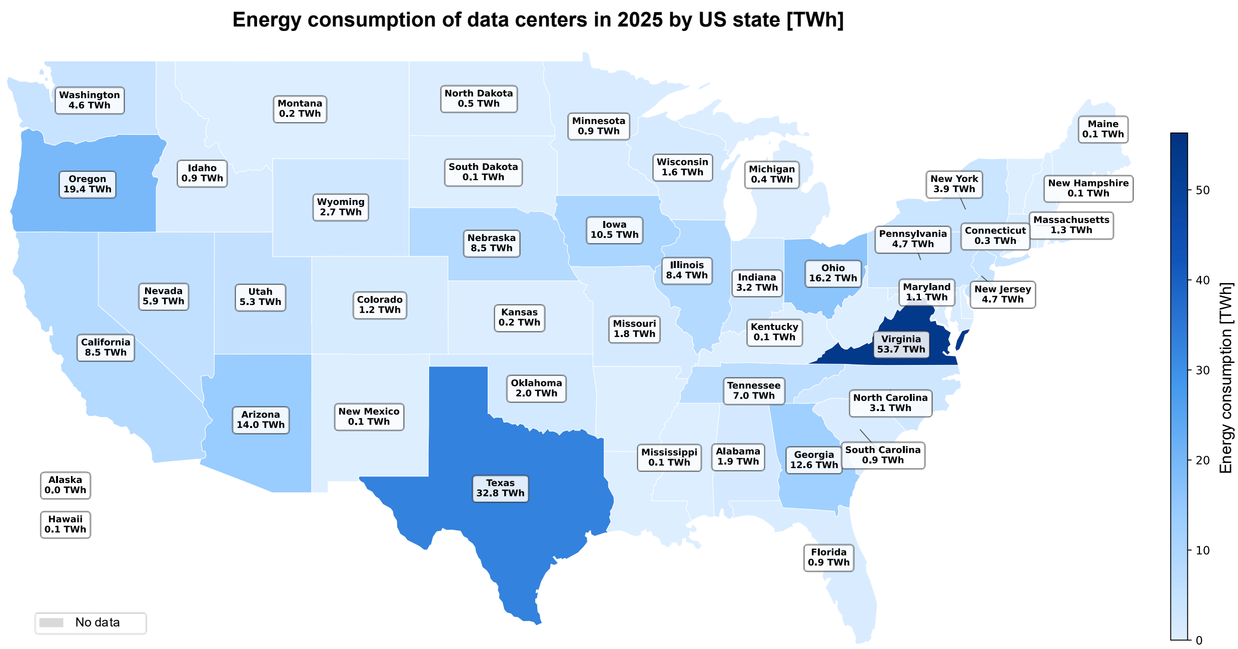


Source: Öko-Institut, analysis of the BloombergNEF database

2.1.3 Energy consumption in the United States of America

There are also significant regional differences within the United States, as shown in Figure 2-2. Of the total 247 TWh of electricity consumed by data centers in the U.S. in 2025, 22% was consumed in Virginia (54 TWh), 13% in Texas (33 TWh), 8% in Oregon, 7% in Ohio, 6% in Arizona, 5% in Georgia, 4% in Iowa, 3% in California, 3% in Nebraska, 3% in Illinois, and 3% in Tennessee. The remaining U.S. states each consume less than 6 TWh, and thus less than 2% of the total.

Figure 2-2 : Energy consumption of data centers in the US in 2025

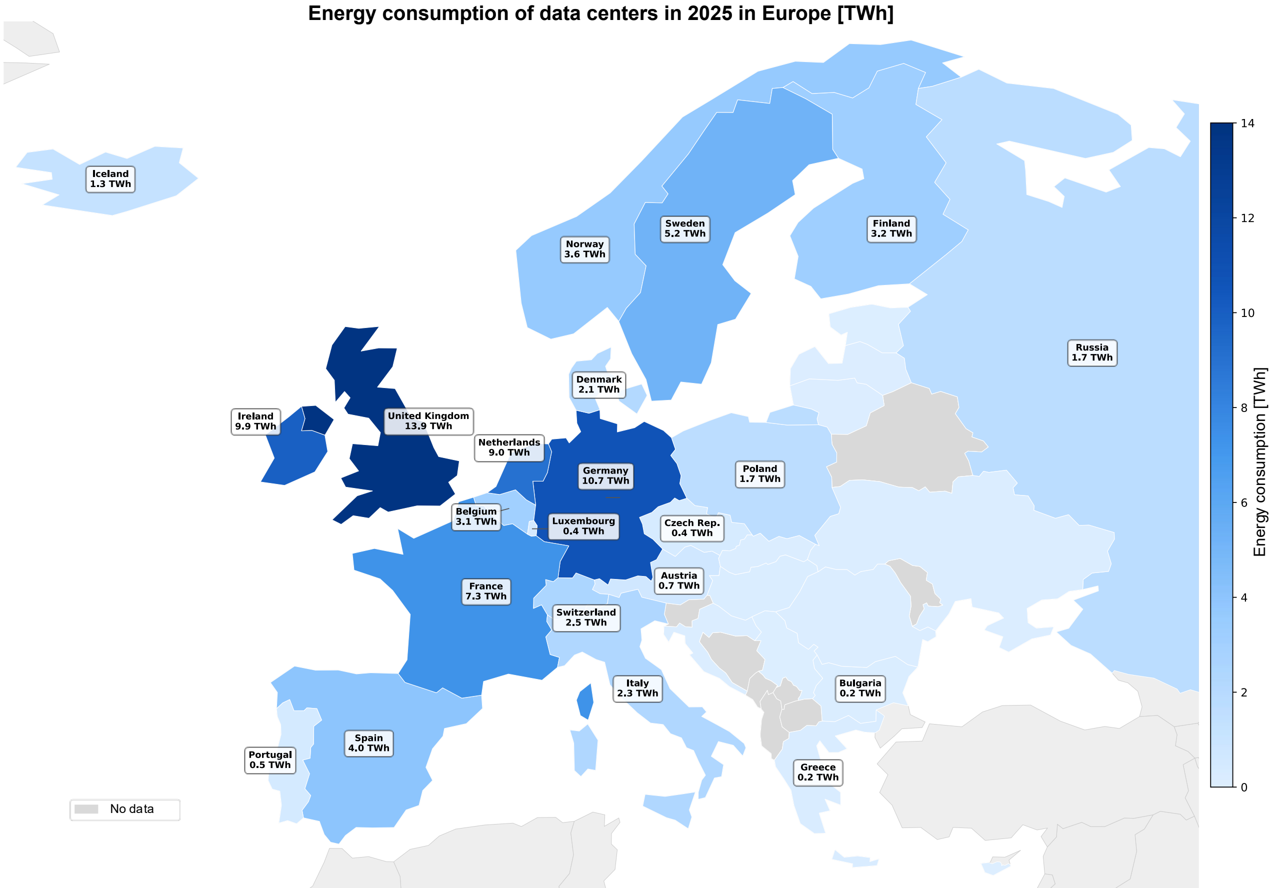


Source: Öko-Institut, analysis of the BloombergNEF database

2.1.4 Energy consumption in Europe

In Europe, energy consumption by data centers is distributed somewhat more evenly, as shown in Figure 2-3. In 2025, European data centers consumed a total of 86 TWh, accounting for approximately 18% of global electricity used by data centers. The United Kingdom leads the way with 14 TWh (16%), followed by Germany with 11 TWh (12%), Ireland with 10 TWh (12%), the Netherlands with 9 TWh (11%), France with 7 TWh (9%), Sweden (5 TWh, 6%), Spain (4 TWh, 5%), Norway (4 TWh, 4%), Finland (3 TWh, 4%), and Belgium (3 TWh, 4%). All other European countries account for less than 3% of electricity consumption for European data centers. Countries whose energy consumption is below 0.1 TWh are not labeled with figures in the figure for the sake of readability. The recorded consumption for Russia is only 1.7 TWh, indicating that there are data gaps here.

Figure 2-3 : Energy consumption of data centers in Europe in 2025

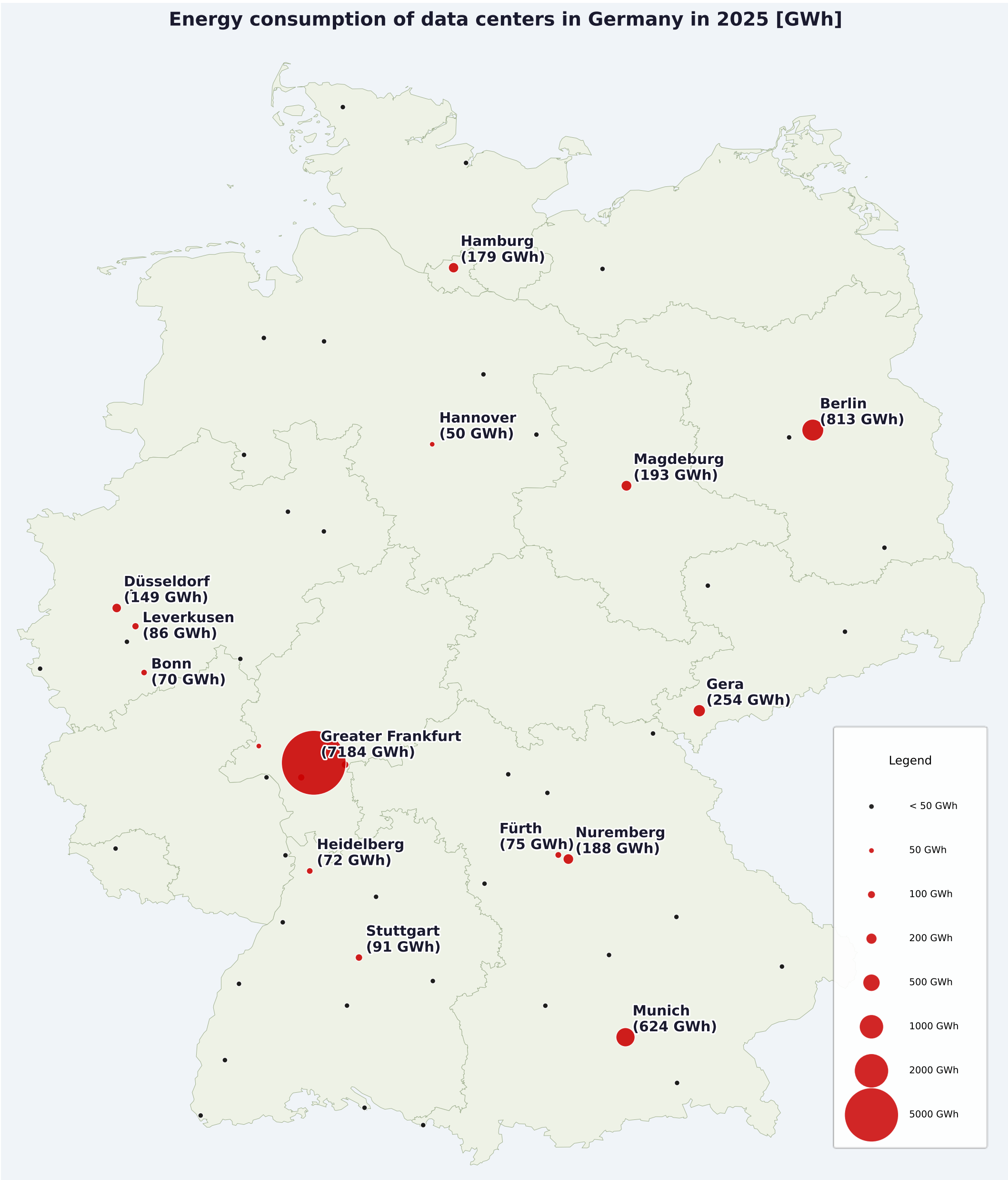


Source: Öko-Institut, analysis of the BloombergNEF database

2.1.5 Energy consumption in Germany

The BloombergNEF database lists approximately 1.4 GW of operational IT capacity in data centers in Germany for the year 2025, resulting in an annual energy consumption of around 10.7 terawatt-hours. This amount of electricity is only about half as much as current estimates for Germany, which range from 22, to 26 TWh (Stobbe et al. 2025). Therefore, it must also be assumed for Germany that there are data gaps regarding data centers and that some locations are not included. The available dataset is illustrated in Figure 2-4 using a map of Germany.

Figure 2-4 : Energy consumption of data centers in Germany in 2025



Source: Öko-Institut, analysis of the BloombergNEF database, labeling for locations ≥ 50 GWh per year

Even within Germany, there are significant regional differences in the distribution of data centers. A clear concentration is found in the Frankfurt metropolitan area, comprising the cities of Frankfurt am Main, Offenbach, Eschborn, Hattersheim, Rüsselsheim, Sossenheim, and Darmstadt, which have been grouped together in the figure as “Greater Frankfurt” for the sake of clarity. The Frankfurt metropolitan area has an annual electricity consumption of 7,184 GWh. The second and third largest locations are Berlin with 813 GWh and Munich with 624 GWh, followed by smaller locations such as Gera with 254 GWh, Magdeburg with 193 GWh, Nuremberg with 188 GWh, and Hamburg with 179 GWh of annual data center electricity consumption.

2.2 CO_2-intensity of computing (CUE)

When calculating a data center’s carbon footprint, it makes a difference whether it is powered, for example, by electricity from coal-fired power plants or by electricity from wind turbines. In the case of a hard coal power plant 860 grams of CO_2-equivalents per kilowatt-hour of electricity (g CO_2e/kWh_{el}) are emitted, whereas only 10 g $CO_2e/kWh_{(el)}$ are emitted in the case of electricity from offshore wind power (seeTable 2-1).

2.2.1 The Carbon Usage Effectiveness metric (CUE)

The *Carbon Usage Effectiveness* (CUE) was defined in the EN 50600 4-8 standard as a metric to describe the CO_2-intensity of data center energy consumption. The metric describes the ratio of greenhouse gas emissions resulting from the data center’s electricity consumption to the electricity consumption caused by the IT equipment:

$$CUE = \frac{data\ center\ CO2e\ emissions\ [g\ CO2e/a]}{electricity\ consumption\ of\ IT\ \ [kWh_{IT}/\ a]} \qquad [g\ CO_2e/kWh_{IT}]$$

To calculate the data center’s greenhouse gas emissions, the total electricity consumption of the data center – which also includes losses from building services (cooling systems, energy conversion) – can be used for simplicity. Electricity consumption is calculated as the product of IT electricity consumption and the PUE metric and multiplied by the emission factor (EF) of the electricity used:

$$data\ center\ CO2e\ emissions = electricity\ consumption\ of\ IT \cdot PUE \cdot EF_{electricity} \qquad [g\ CO_2e/a]$$

This is a simplification, as data centers can also generate direct greenhouse gas emissions through the escape of refrigerants, shielding gases from switchgear, or emissions from backup power systems (e.g., diesel generators), as well as CO_2 emissions associated with the manufacturing of IT equipment and building systems. In the overall balance, however, the electricity-related CO_2 emissions of a data center account for the vast majority of total emissions, at 81–98% (Gröger and Liu 2021).

If the formula to calculate the data center’s CO_2e emissions is inserted into the CUE formula, the annual electricity consumption of the IT equipment cancels out, leaving a formula that contains only the PUE and the emission factor (EF) of the electricity used:

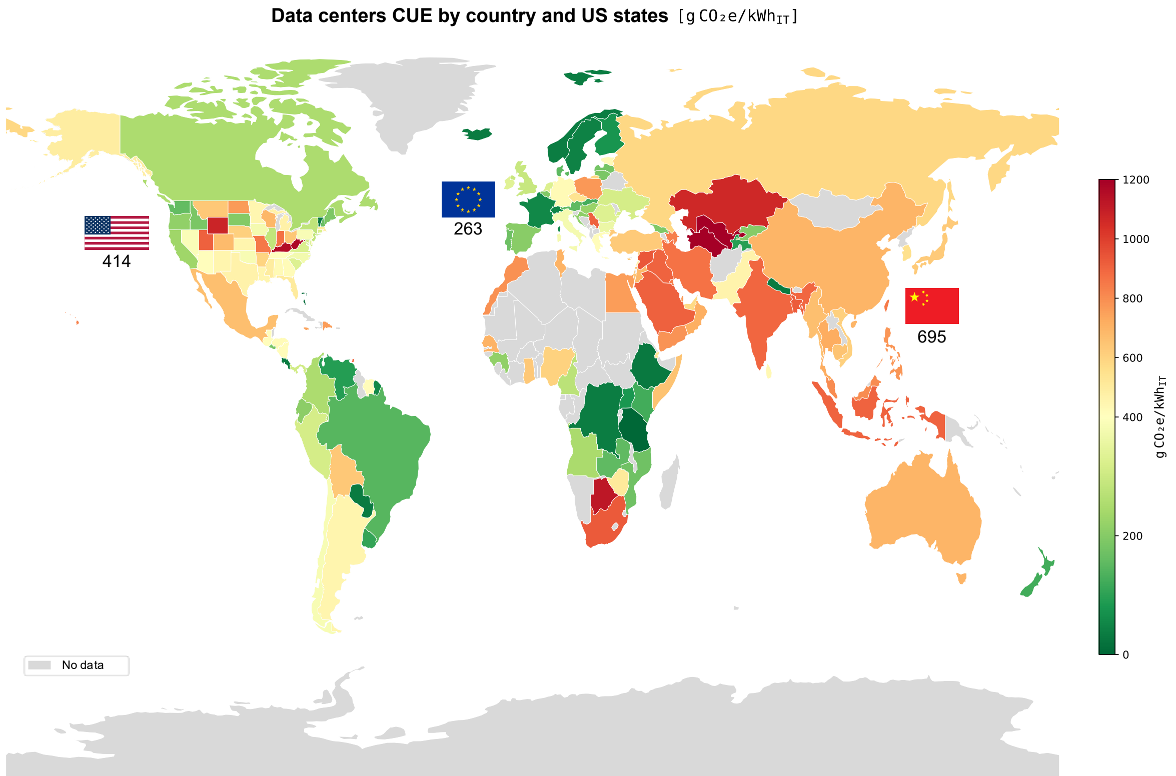
$$CUE = PUE \cdot EF_{electricity} \qquad [g\ CO_2e/kWh_{IT}]$$

2.2.2 CUE World Map

Using this formula for *Carbon Usage Effectiveness* (CUE), we present the CO_2-intensity of computing operations below. It depends both on the efficiency of the building systems (PUE) and on the local electricity mix. For the PUE values, we either used the existing values from the database, which range from 1.03 to 2.9, or, in cases of data gaps averaged values between 1.31 and 1.4 - depending on the data center's operating model. The emission factors ($EF_{electricity}$) for local electricity are taken from Ember Energy's country-specific database for the year 2025 (Ember Energy 2026) and, for the United States, from data provided by the U.S. Environmental Protection Agency (EPA) for the year 2023 (EPA 2025).

Figure 2-5 shows a world map of the regional distribution of CO_2-intensity in computing.

Figure 2-5 : Regional distribution of the CO_2-intensity of computing



Source: Öko-Institut, analysis of the BloombergNEF database combined with EMBER and EPA emission factors

Among the ten largest data center locations, India leads significantly in terms of the carbon intensity of computing operations, with a CUE of 900 grams of CO_2-equivalents per kilowatt-hour for the operation of IT equipment (g CO_2e/kWh_{IT}), followed by Australia with 698 g COe/kWh_{IT}, China with 695 g CO_2e/kWh_{IT}, Japan with 630 g CO_2e/kWh_{IT}, Germany with 430 g CO_2e/kWh_{IT}, and the United States with a nationwide average of 414 g CO_2e/kWh_{IT}. Other countries in the top 10 data center electricity consumers are below 400 g CO_2e/kWh_{IT}. The energy-consumption-weighted average of the CUE value for all European countries (simplified here as an EU flag) is 263 grams of CO_2-equivalents per kilowatt-hour of IT electricity.

The calculation of the CUE also shows that countries which currently do not yet have significant data center capacity have an above-average CUE value. In Europe, these include, in particular, Serbia with 911 g CO_2e/kWh_{IT}, Poland with 771 g CO_2e/kWh_{IT}, Cyprus with 643 g CO_2e/kWh_{IT}, Malta with 635 g CO_2e/kWh_{IT}, and Turkey with 627 g CO_2e/kWh_{IT}. In North Africa, only a few data centers are included in the database. But high CUE values are also evident here, with Morocco at 793 g CO_2e/kWh_{IT} and Egypt at 757 g CO_2e/kWh_{IT}. In southern Africa, the Republic of Botswana stands out significantly with 1125 g CO_2e/kWh_{IT} and South Africa with 926 g CO_2e/kWh_{IT}. Similarly, the Gulf region, with values around 900 g CO_2e/kWh_{IT} , as well as Central Asia – particularly Turkmenistan (1711), Uzbekistan (1313), and Kazakhstan (1067) – exhibit high specific greenhouse gas emissions per unit electricity for the operation of IT equipment. Other hotspots in Asia include Hong Kong, Bangladesh, and Indonesia, with values around 900 g CO_2e/kWh_{IT} ,as well as Taiwan, Malaysia, and the Philippines, with values around 800 g CO_2e/kWh_{IT}.

In summary, regarding CUE values, it can be concluded that the location where a data center is built and the power grid from which it draws its electricity make a significant difference in its greenhouse gas emissions.

2.2.3 CUE in the United States

Within the United States, we examined individual states in greater detail and presented the data in Figure Figure 2-5 as there are also significant differences in the CO_2-intensity of computing operations depending on the data center's location. Of the 10 largest data center locations, 4 have CUE values significantly above the national average of 414 g CO_2e/kWh_{IT}. These are the U.S. states of Ohio with 640 g CO_2e/kWh_{IT}, Nebraska with 612, Texas with 468, and Georgia with 424 g CO_2e/kWh_{IT}. In these U.S. states, a total of approximately 9 GW are currently operational, and approximately 5 GW of data centers are still under construction. Once operational, the newly built data centers will be responsible for additional emissions of at least 14 million metric tons of CO_2 equivalents.

Other U.S. states that are not among the top 10 data center locations have even higher specific greenhouse gas emissions per unit electricity for the operation of IT equipment. The ten most CO_2-intensive U.S. states, in descending order, are West Virginia (1,171), Kentucky (1,156), Wyoming (1,077), Utah (908), Indiana (873), Missouri (855), Hawaii (831), North Dakota (764), Wisconsin (690), and Colorado (676 g CO_2e/kWh_{IT}).

The United States of America is divided into 27 electric power market areas, which differ in size from the 50 states, encompass multiple states, and partially overlap. Therefore, a clear assignment of CUE values to the US states is not always accurate. For state-specific emission factors, the U.S. Environmental Protection Agency (EPA) has therefore provided average values. In regions served by multiple power grid regions, however, the electricity can be either low-carbon or high-carbon. This is the case, for example, in north-central Wyoming, which is supplied by either the WECC Northwest or the WECC Rockies, whose emission factors differ by a factor of 2. For individual data center locations, it is therefore necessary to verify which power grid actually supplies the electricity.

2.2.4 Supply from on-site power plants

Newly built data centers specializing in artificial intelligence (AI) now have connected loads ranging from several hundred megawatts (MW) up to 1 gigawatt (GW) or more. It is extremely difficult to integrate such new power consumers into existing power grids, as their power generation and transmission capacities are insufficient for this purpose. A current trend in the development of new data centers is therefore the parallel construction of new dedicated power generation capacity. Under the slogan "Bring your own power" (van Osdol and Hughes 2026), **new gas-fired power plants** are being built on-site, for example, enabling the data center to operate independently of the local power grid. For example, the energy company E.ON is currently building a gas-fired power plant with an electrical output of 61 MW for the colocation provider CyrusOne in Frankfurt-Griesheim (Blum 2025). One of the prerequisites for the construction of gas-fired power plants is the availability of local natural gas networks with sufficient capacity.

Example: xAI's own gas turbines

If a data center is supplied by its own power plant, this has a direct impact on its CO_2 intensity. For example, to supply the two "Colossus" AI data centers 1 and 2 in Memphis, Tennessee, xAI (Elon Musk's company) operates a total of 56 gas turbines on-site to supply the data center self-sufficiently (Rozier 2026).

With an electricity generation efficiency of 40% for these standalone turbines and an assumed PUE of 1.32, the AI data centers achieve a CUE value of 727 g CO_2e/kWh_{IT}, which is nearly twice as high as the local CUE value of 396 g CO_2e/kWh_{IT} if they were to draw power from the grid. The result is that the data centers, with their total IT connected load of 424 MW, emit not 1 million metric tons of CO_2 equivalents per year, but 1.8 million metric tons – 84% more than if they were supplied by the public power grid in Tennessee.

Just as xAI has opted for a particularly climate-damaging energy supply by operating its own fossil-fuel-fired power plants, investing in **wind farms or solar power plants** can also specifically reduce the carbon footprint of computing operations. However, this is only the case if the power generation facilities and the data center are physically connected via power lines. Instead of investing in new fossil fuel power plants, data center operators can therefore also generate clean energy.

If xAI were to operate the aforementioned AI data centers using its own physically connected onshore wind farms, it would be responsible for only 57,000 metric tons of CO_2-equivalents per year and would reduce its CO_2 emissions by 97% compared to the current setup using gas turbines.

Table 2-1 shows the **emission factors** of **various power generation technologies** and the resulting CUE values based on an assumed average PUE of 1.36. The emission factors include not only direct emissions but also emissions for building and manufacturing and the auxiliary energy needed by the respective power plants.

Table 2-1: CO_2-intensity of computing (CUE) depending on the type of power generation

Power generation technology	Emissions factor for electricity generation [g CO_2e/kWh_{el}]	PUE [-]	CUE [g CO_2 e/kWh_{IT}]
Hydropower	3	1.36	4
Wind power (offshore)	10	1.36	13
Onshore wind power	18	1.36	24
Nuclear power	18	1.36	25
Photovoltaics	57	1.36	77

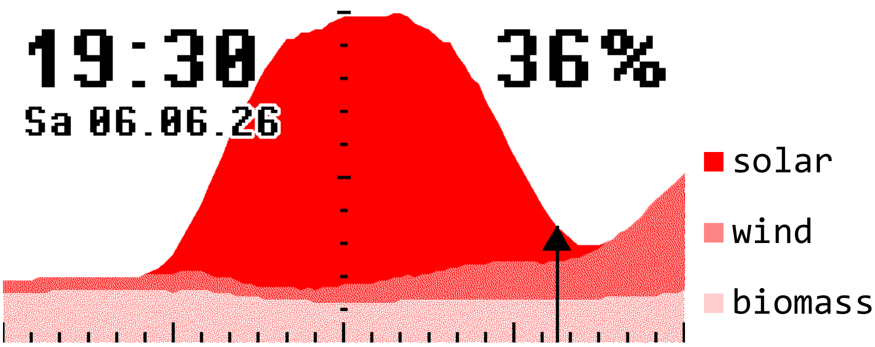
Power generation technology	Emissions factor for electricity generation [g CO_2e/kWh$_{el}$]	PUE [-]	CUE [g CO_2 e/kWh$_{IT}$]
Natural gas (combined cycle power plant)	394	1.36	536
Natural gas (stand-alone gas turbine)	551	1.36	750
Hard coal	860	1.36	1,170
Lignite	1,119	1.36	1,522

Source: Öko-Institut using data from the Federal Environment Agency (Lauf et al. 2025; Icha and Lauf 2026) as well as own calculations

If a data center is powered by electricity from renewable sources, there are daily and seasonal fluctuations in the amount of renewable electricity generated. This daily pattern is illustrated inFigure 2-6 for a windless but sunny day in Germany.

To enable a fully renewable energy supply for the data center around the clock, **solar and wind power** must be temporarily stored **in battery storage systems** and discharged during periods of low sunlight and low wind. In addition to the energy required to generate solar and wind power, greenhouse gas emissions from the production of the battery storage systems and charging losses must also be taken into account. The level of specific greenhouse gas emissions from this renewable electricity, which is available around the clock, could not be determined within the scope of this study. However, it is expected that these specific emissions are significantly lower than those of fossil-fuel-generated electricity.

Figure 2-6 : Example: Daily curve of renewable electricity generation



Source: Öko-Institut, own illustration using electricity market data from the Federal Network Agency (smard.de)

Instead of tailoring power generation or storage to the data center's needs, data centers themselves can also make their power consumption more flexible. Non-time-critical computing tasks, such as training AI models, can, for example, be shifted to times of day when solar and wind energy are abundant. This strategy of making data centers more flexible (Bauknecht et al. 2026) also contributes to reducing the CO_2-intensity of computing (CUE).

2.3 Radioactive waste from computing (RWUE)

The environmental impacts of electricity production are not limited to greenhouse gas emissions. When electricity is generated in nuclear power plants, as in France or Ukraine, for example, greenhouse gas emissions per kilowatt-hour are lower than in fossil fuel power plants, as shown in

Table 2-1; however, highly radioactive waste is also produced. Generating one megawatt-hour [MWh_{el}] of electricity produces between 2 and 3 grams [g] of spent fuel elements, which must ultimately be disposed of as highly radioactive waste and stored safely for thousands of years. The exact amount of waste per unit of electricity depends on the design of the nuclear power plant and its efficiency. For the labeling of electricity under the German Energy Industry Act (EnWG), the German energy industry (BDEW 2024) has set the waste volume at 2.7 grams per megawatt-hour of electricity (g/MWh_{el}). For the sake of simplicity, this figure is used to calculate radioactive waste volumes for all nuclear power plants, regardless of their design.

Similar to the definition of energy losses in data center building systems, *Power Usage Effectiveness* (PUE), and the metric for the CO_2-intensity of computing workloads, *Carbon Usage Effectiveness* (CUE), a metric for the specific amount of high-level radioactive waste per unit electricity consumption of the IT is defined below. In line with the other metrics, this is designated as *Radioactive Waste Usage Effectiveness* (RWUE):

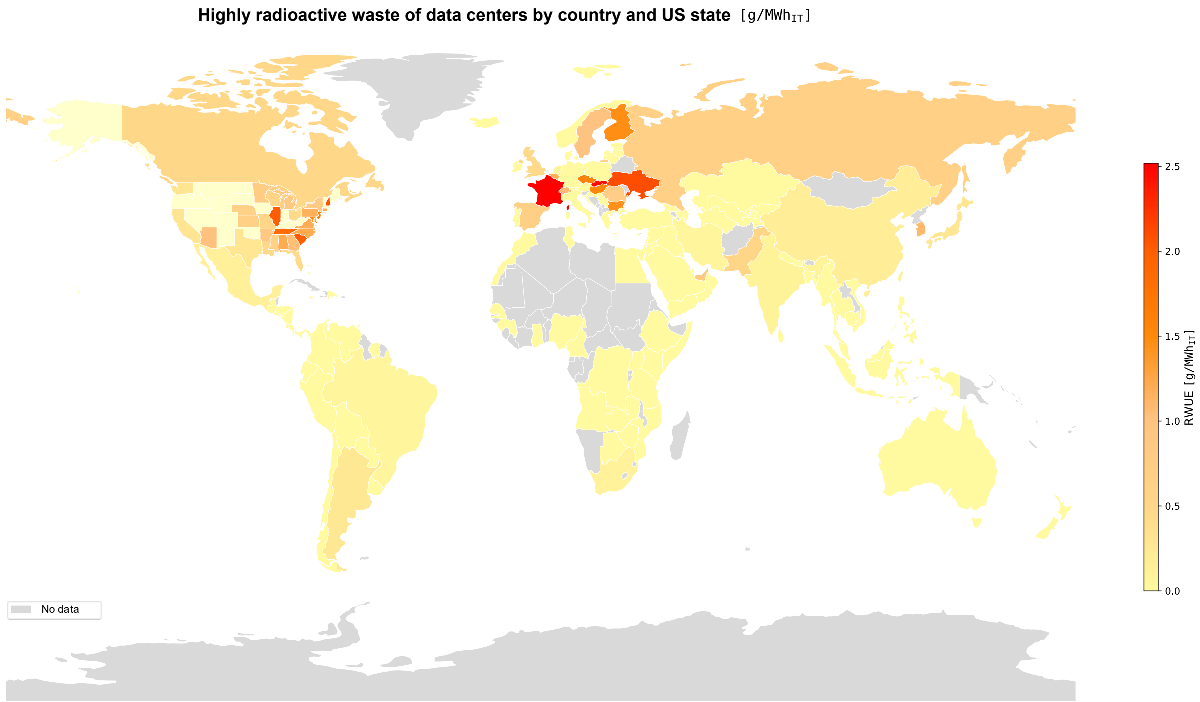
$$RWUE = \frac{amount\ of\ radiactive\ waste\ [g/a]}{electricity\ consumption\ of\ IT\ [MWh_{IT}/a]} \qquad [g/MWh_{IT}]$$

The RWUE metric can be used to calculate the amount of radioactive waste generated during the operation of a data center’s IT equipment. Since the electricity consumption of the entire data center is higher than the electricity consumption of the IT equipment alone by a factor of PUE, the RWUE can also be calculated using the following formula:

$$RWUE = PUE \cdot Share\ of\ nuclear\ [\%] \cdot 2{,}7\ g/MWh \quad [g/MWh_{IT}]$$

This calculation was performed for the data center locations in the BNEF database and is presented in the following world map (Figure 2-6). Countries with a particularly high proportion of radioactive waste per unit electricity consumption of the IT are shown in red, while countries with no radioactive waste are shown in light yellow. Particularly high amounts of radioactive waste are generated by data centers in countries with a high share of nuclear power, namely France (2.5 g/MWh_{IT}), Slovakia (2.5 g/MWh_{IT}), and Ukraine (2.1 g/MWh_{IT}), followed by several U.S. states, which are shown separately on this map. The U.S. average for radioactive waste per unit electricity consumption of the IT is 0.7 g/MWh_{IT}. Countries known for having a high share of renewable energy but also operating nuclear power plants, such as Finland (1.5), Switzerland (1.1), and Sweden (1.0), stand out clearly in the RWUE representation.

Figure 2-7: Radioactive waste volumes of electricity generation for computing



Source: Öko-Institut, analysis of the BloombergNEF database combined with EMBER and EPA nuclear power shares

The following Table 2-2 lists the values for radioactive waste quantities per unit electricity for the operation of IT (RWUE) for those countries and U.S. states that have values greater than or equal to 1.0 g/MWh$_{IT}$.

Table 2-2: Radioactive waste quantities per unit of computational work (RWUE)

Country and U.S. State	**Radioactive waste quantities per unit electricity consumption of the IT RWUE** [g/MWh$_{IT}$]
France	2.5
Slovakia	2.5
Ukraine	2.1
USA - New Hampshire	2.1
USA - South Carolina	2.0
USA - Illinois	2.0
USA - Tennessee	1.8
USA - New Jersey	1.6
Czech Republic	1.6
USA - Maryland	1.5
Hungary	1.5
Finland	1.5
Bulgaria	1.4
USA - Connecticut	1.2
USA - North Carolina	1.2
USA - Alabama	1.2

Country and U.S. State	**Radioactive waste quantities per unit electricity consumption of the IT** **RWUE** [g/MWh_{IT}]
USA - Virginia	1.2
Belgium	1.2
USA - Pennsylvania	1.2
South Korea	1.1
Switzerland	1.1
USA - Georgia	1.0
USA - Arizona	1.0
Sweden	1.0

Note: The list includes countries and U.S. states with values ≥ 1.0 g/MWh_{IT}
Source: Öko-Institut, analysis of the BloombergNEF database combined with EMBER and EPA nuclear power shares

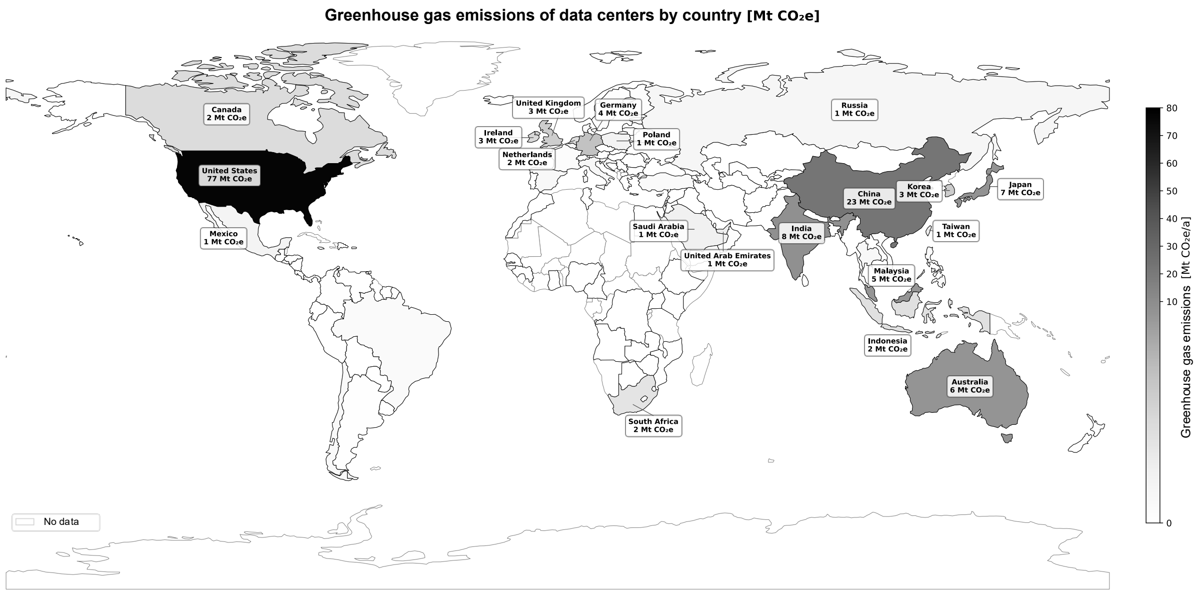
The amount of high-level radioactive waste generated by individual data centers is significant. Currently built and planned data centers, particularly those for AI applications, have a power consumption of the installed IT of 100 MW or a multiple thereof. The servers and storage systems of a 100 MW data center require approximately 580,000 MWh_{IT} per year. If such a data center is operated in Sweden, with an RWUE of 1.0 g/MWh_{IT}, it generates approximately 0.6 metric tons of high-level radioactive waste annually. In Finland, with an RWUE of 1.5 $g/MWh_{(IT)}$,the data center is responsible for approximately 0.9 metric tons. In the U.S. state of South Carolina, with an RWUE of 2.0 g/MWh_{IT}, the figure is around 1.2 metric tons. And in France, with an RWUE of 2.5 $g/MWh_{(IT)}$ the 100 MW data center generates around 1.5 metric tons of high-level radioactive waste annually.

2.4 Greenhouse gas emissions from data centers

Regional absolute greenhouse gas emissions are calculated based on data center energy consumption and the corresponding local emission factors. By 2025, data centers worldwide will be responsible for greenhouse gas emissions amounting to at least 170 million metric tons of CO_2-equivalents (Mt CO_2e/a). This figure refers to the data centers included in the analyzed BloombergNEF database. The actual emissions could be twice as high, but this cannot be verified due to a lack of transparency on the part of data centers and technology companies.

Figure 2-8 shows a world map of the regional distribution of greenhouse gas emissions from data centers. The grayscale is chosen so that differences are visible even in the lower range from 0 to 10 Mt CO_2e/a. In addition to the color coding, the figure also provides labels for the 20 largest CO_2-emitter countries.

Figure 2-8: Greenhouse gas emissions from data centers worldwide in 2025



Source: Öko-Institut, analysis of the BloombergNEF database combined with EMBER and EPA emission factors

The list of countries with the highest greenhouse gas emissions from data centers is clearly led by the United States of America. In 2025, data centers in the U.S. generated emissions totaling 77 million metric tons of CO_2 equivalents (Mt CO_2e/a), China 23 Mt CO_2e/a, India 8 Mt CO_2e/a, Japan 7 Mt CO_2e/a, Australia 6 Mt CO_2e/a, Malaysia 5 Mt CO_2e/a, Singapore 4 Mt CO_2 e/a, and Germany also 4 Mt CO_2e/a. All other countries have data center emissions of 3 Mt CO_2 e/a or less.

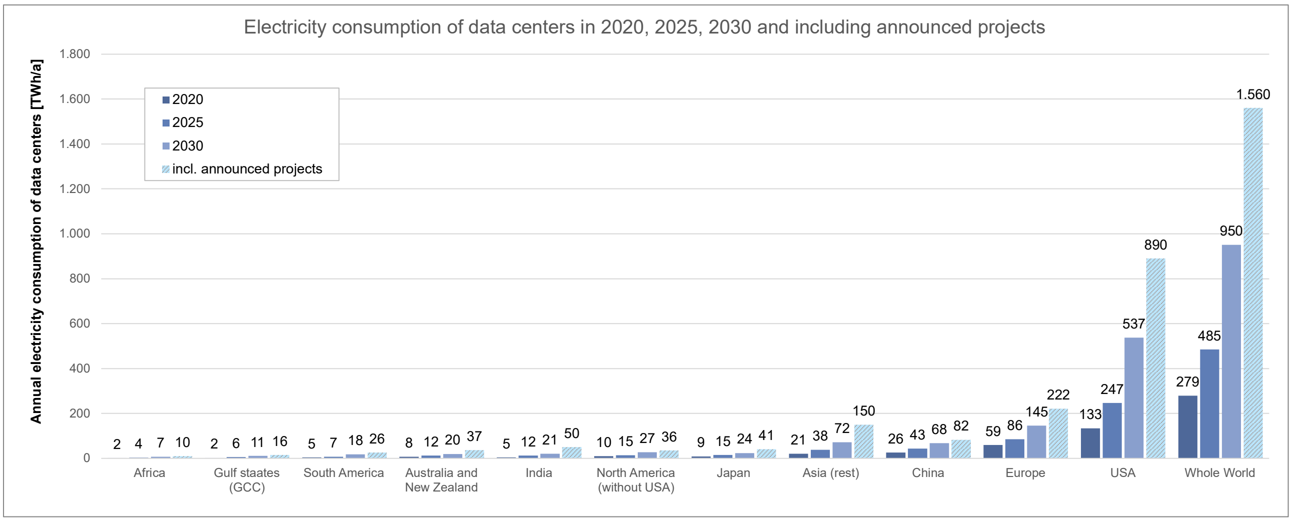
3 Development from 2020 to 2030

The figures in Section 2 Regional Distribution of Data Centers refer to the year 2025. The figures calculated there for energy consumption and greenhouse gas emissions already pose a threat to the current energy infrastructure and the achievement of climate protection goals. A particular challenge posed by data centers is their exponential growth. Between 2020 and 2025, there was already a significant expansion of data center capacity, a trend that will continue in the coming years. The dataset analyzed here shows that a large number of additional data centers are already in the construction or planning phases, suggesting a further increase in energy consumption and greenhouse gas emissions.

3.1 Development of energy consumption

The following Figure 3-1 illustrates how data center energy consumption has increased between 2020 and 2025 and is projected to continue evolving through 2030. For data center expansion and new construction projects currently in the construction phase, a forecast is provided for the year 2030, which, in terms of global energy consumption, is on the same order of magnitude as the International Energy Agency's forecast for the year 2030, namely 950 TWh (IEA 2026). It is assumed that all construction projects already underway will be completed by 2030 and that the IT equipment will, on the whole, have a higher utilization rate compared to 2025. In addition, all announced projects listed in the BloombergNEF database are assumed to be realized. These figures represent an upper limit for data center expansion, as it is reasonable to assume that not all announced projects will actually be realized by 2030.

Figure 3-1 : Development of data center electricity consumption from 2020 to 2030



Source: Öko-Institut, analysis of the BloombergNEF database combined with EMBER emission factors for 2025

The energy consumption of data centers is broken down by region in Figure 3-1. The United States, China, Japan, and India – which lead the world in data center energy consumption – are shown separately, and the larger geographic regions containing these countries (Asia and North America) are then shown without these individual countries. In addition, the Gulf States (Gulf Cooperation Council: United Arab Emirates, Saudi Arabia, Qatar, Oman, Bahrain, Kuwait) were excluded from the Asian continent and presented separately.

Global trends in electricity consumption by data centers show that energy demand stood at 279 TWh in 2020 and had nearly doubled to 485 TWh by 2025 (a factor of 1.7). The forecast for 2030, at 950 TWh, represents another doubling in just 5 years (a factor of 2.0). If all currently announced projects were to be implemented, electricity consumption would rise to 1,560 TWh, which would correspond to more than a threefold increase from the 2025 figure (factor of 3.2). A particularly rapid and, in absolute terms, substantial growth is occurring in the United States. From 2020, with a value of 133 TWh, to 2025, with electricity consumption of 247 TWh, the growth is still in line with the global trend (factor of 1.9). From 2025 to 2030, when U.S. data center electricity consumption is projected to reach 537 TWh, it will have more than doubled (factor of 2.2). If all announced U.S. projects were implemented, data center electricity consumption in the U.S. would nearly quadruple to 890 TWh (factor of 3.6).

3.2 Trends in the CO_2-intensity of computing (CUE)

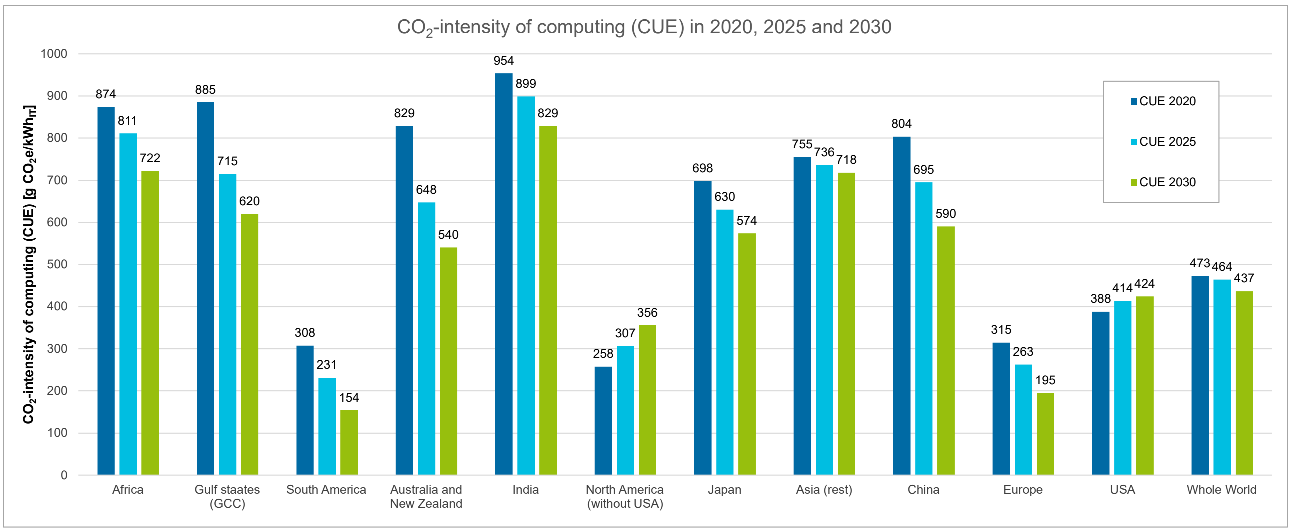
The expansion of new data center capacity is occurring in parallel with the global expansion of renewable energy for electricity generation, which results in a reduction in specific CO_2 emission factors. Hence, the absolute greenhouse gas emissions from data centers should increase at a slower rate than their energy consumption.

However, the regional distribution of data centers is also causing shifts that deviate from the global trend. In regions where new data centers are primarily built in areas where electricity is generated mainly from coal and gas, emissions may grow even faster than energy consumption. This is the case in some parts of North America (including Mexico), but especially in the U.S. Of the total 17.5 GW of IT capacity currently under construction in the U.S., 7.5 GW is being built in states where CUE values are higher than the U.S. average (particularly Texas, Georgia, Ohio, Indiana, Wisconsin, Missouri, and Wyoming). Existing fossil-fuel-fired power plants in these states are being operated longer and more intensively to power data centers.

To calculate greenhouse gas emissions, the emission factors of the regional electricity mixes are used, analogous to Section 2.4. For the U.S. states: EPA (2025) and for the rest of the world: Ember-Energy (2026). For the forecast for the year 2030, the trend in emission factors for the rest of the world over the past 5 years was extrapolated through to 2030. For the U.S. states, however, the emission factors were kept constant, as the expansion of renewable energy generation in the U.S. is currently slowed down by political opposition. In some locations in the U.S., new fossil fuel power plants are even being built to power data centers. According to estimates by the International Energy Agency's (IEA 2026), approximately 80 GW of natural gas power plants for on-site power supply to data centers are currently under construction in the U.S. In some areas in the northeastern U.S., where the expansion of data centers is particularly rapid, this is already causing emission factors to rise (Open Energy Outlook 2025). However, since such data is not available for all U.S. states, the following calculations assume consistent specific greenhouse gas emissions from electricity generation across all U.S. states. Against this backdrop, the forecast of CUE values and greenhouse gas emissions for the U.S. represents a rather conservative estimate.

Figure Figure 3-2 first illustrates the CO_2-intensity of computing (CUE) (see Section 2.2.1), which describes the CO_2 emissions associated with computing in each region and how this value will change between 2020 and 2030.

Figure 3-2 : Development in the CO_2-intensity of computing (CUE)



Source: Öko-Institut, analysis of the BloombergNEF database combined with EMBER and EPA emission factors for 2025

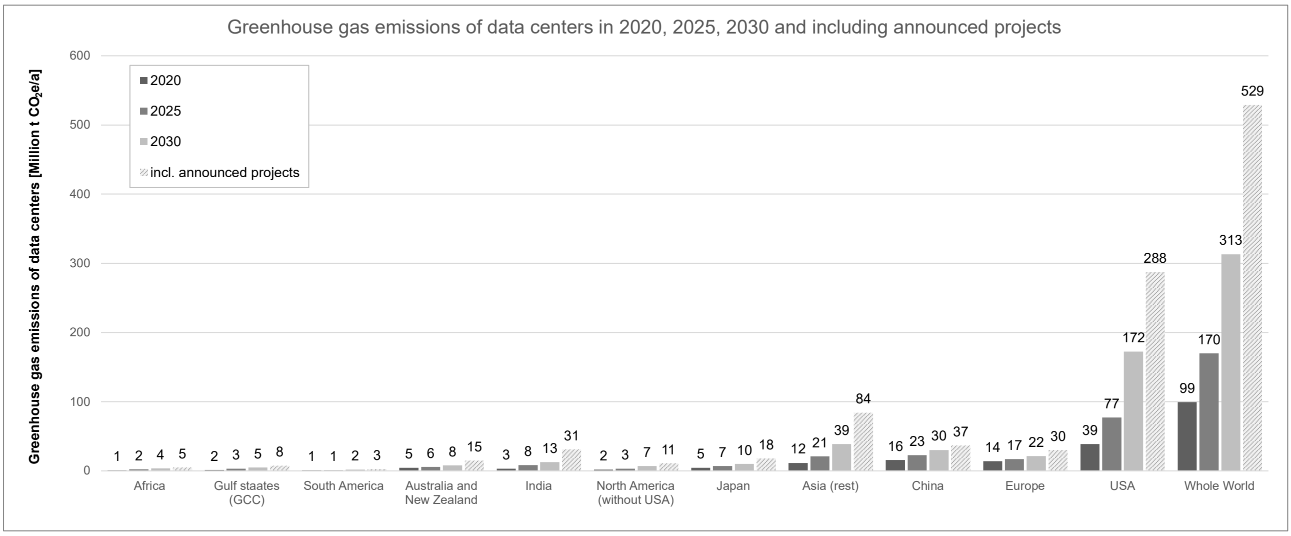
In nearly all regions, the carbon intensity of computing (CUE) is declining in line with the global trend. Among the three largest data center locations – the U.S., China, and Europe – CUE values are improving in China and Europe. In China, values are projected to fall from 804 g CO_2e/kWh_{IT} in 2020 to 590 g in 2030, via 695 g in 2025. In Europe, they are falling from 315 g CO_2e/kWh_{IT} in 2020 to 195 g in 2030, via 263 g in 2025. In the U.S., however, specific greenhouse gas emissions from data center operations will rise from 388 g CO_2e/kWh_{IT} in 2020 to 414 g in 2025 and 424 g CO_2e/kWh_{IT} in 2030. In 2030, the CO_2 footprint of computing in the U.S. will be more than twice as high as the European figure of 195 g CO_2e/kWh_{IT}. Figuratively speaking, twice as much CO_2 will then be released in the U.S. for the same computing task. If the trend of building new fossil fuel power plants in the U.S. continues, this CUE value could rise even further in the future, making computing even more CO_2-intensive.

3.3 Development of greenhouse gas emissions

The development in greenhouse gas emissions from data centers is determined by regional energy consumption and the regional emission factors of the electricity supply. As shown in Section 3.2, local emission factors in the U.S. are kept constant, while at other locations the trend of the past 5 years is projected to continue through 2030.

Figure Figure 3-3 shows the development of greenhouse gas emissions in the selected regions.

Figure 3-3 : Development of greenhouse gas emissions from data centers until 2030



Source: Öko-Institut, analysis of the BloombergNEF database combined with EMBER and EPA emission factors

Globally, greenhouse gas emissions from data centers have risen by a factor of 1.7 from 99 million metric tons of CO_2-equivalents per year (Mt CO_2e/a) in 2020 to 170 Mt CO_2e/a by 2025. In the next 5 years, by 2030, emissions will have risen to 313 Mt CO_2e/a, corresponding to a factor of 1.8. If all announced projects are implemented, global emissions from data centers will even rise to 529 Mt CO_2e/a, 3.1 times the amount in 2025. There is particularly high growth in greenhouse gas emissions in the U.S., where emissions will rise from 77 Mt CO_2e/a in 2025 to 172 Mt CO_2e/a in 2030, a 2.2-fold increase. If all announced projects are implemented in the U.S., emissions will rise to as much as 288 Mt CO_2e/a, which is 3.7 times the 2025 emission level.

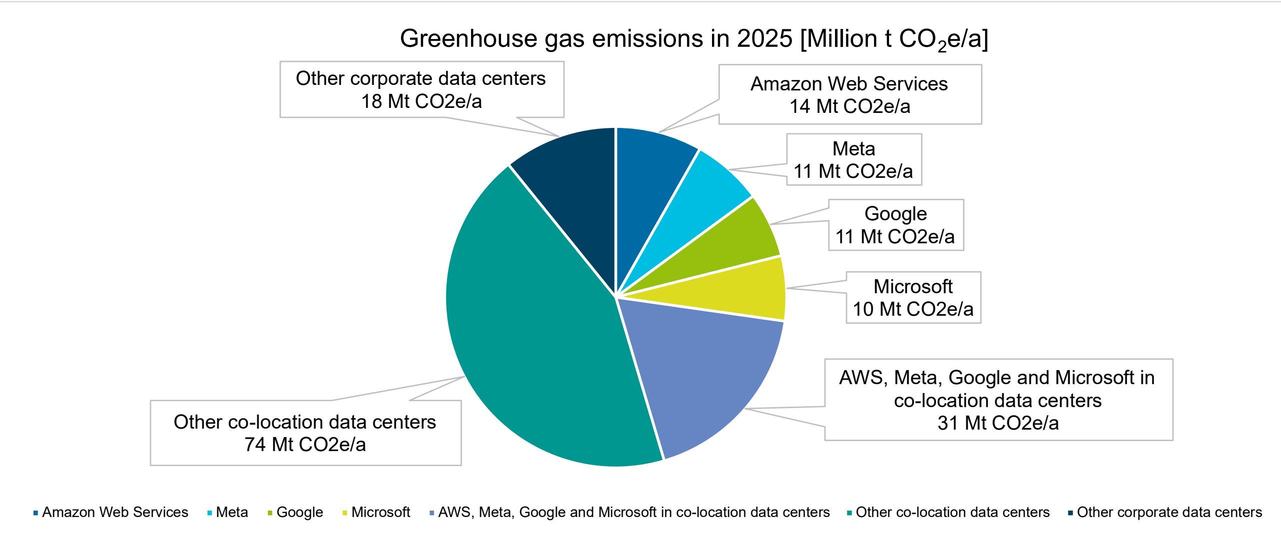
4 Individual companies' greenhouse gas emissions

The BloombergNEF dataset also includes the names of the companies and institutions that operate the approximately 6,700 listed data centers. These include both private-sector companies as well as universities, research institutions, and government agencies. About 1,000 of these companies operate their data centers alongside their own server and storage systems and are therefore responsible for both building services and IT infrastructure ("corporate data centers"). The remaining approximately 1,300 companies are so-called colocation providers, which provide the data center buildings with the associated building services, where IT operators can set up their own IT equipment as customers.

However, an analysis of individual companies' contributions to global greenhouse gas emissions in 2025 makes it clear that the size of these companies varies greatly. Half of all greenhouse gas emissions – totaling 170 Mt CO_2e – are generated by just 16 different data center operators: Amazon Web Services (AWS) (8.2%), Meta (6.7%), Google (6.2%), Microsoft (6.2%), Digital Realty (3.0%), Equinix (2.8%), NTT Global Data Centers (2.7%), GDS Holdings (2.6%), QTS Datacenters (2.3%), ChinData Group (1.7%), CyrusOne (1.4%), Vantage Data Centers (1.3%), AirTrunk (1.3%), STACK Infrastructure (1.0%), Compass Datacenters (1.0%), and China Unicom (1%).

The first four of these (AWS, Meta, Google, Microsoft) operate their own IT infrastructure, meaning they run corporate data centers. The remaining 12, on the other hand, operate colocation data centers and offer data center space to customers. Industry estimates suggest that the major tech companies, the so-called hyperscalers, operate only 60% of their IT capacity themselves and outsource 40% of their server and storage systems to colocation data centers (Synergy Research Group 2025). This means that the four major hyperscalers, in addition to the greenhouse gas emissions from their own corporate data centers, also generate emissions from the leased colocation data centers. In addition to the 46 Mt CO_2e in their own data centers, AWS, Meta, Google, and Microsoft are also responsible for 31 Mt CO_2e/a in colocation data centers. Of the total 170 Mt CO_2 e/a in 2025, the four major hyperscalers are responsible for 77 million metric tons of CO_2 equivalents per year, accounting for 45% of global emissions from data centers. The following Figure 4-1 illustrates this relationship.

Figure 4-1 : Share of the 4 major hyperscalers in total emissions



Source: Öko-Institut, analysis of the BloombergNEF database combined with EMBER emission factors for 2025

The 10 companies with the highest greenhouse gas emissions from their own data centers and IT infrastructures are listed atTable 4-1. Together, these top 10 companies generated 52 Mt CO_2e/a in 2025. This represents approximately 81% of the total 65 Mt CO_2e/a generated by all corporate data centers combined.

To calculate greenhouse gas emissions from energy consumption, the emission factors of the regional public power grid were used as a basis. This did not take into account whether data centers operate their own power generation facilities. This data is not available for all data centers across the board. At least for xAI, it is known that it is supplied on-site by its own natural gas power plants (see Section 2.2.4). In this case, the CUE value increases to 727 g CO_2e/kWh_{IT}. This specific case is shown in parentheses in the figure. It must also be assumed that the CUE values and absolute greenhouse gas emissions for the other operators are higher if they operate their own gas turbines or other fossil-fuel-powered power plants. These individual cases were not taken into account in the following Table Table 4-1.

Table 4-1: Top 10 Corporate Data Centers by Greenhouse Gas Emissions in 2025

No.	Companies with their own data centers	Average CUE [g CO_2e/kWh_{IT}]	Energy consumption [TWh/a]	Greenhouse gas emissions [Mt CO_2e/a]
1	Amazon Web Services	432	44	14
2	Meta	469	32	11
3	Google	440	32	11
4	Microsoft	430	33	10
5	Tencent	714	2.5	1.3
6	Alibaba	688	2.3	1.2
7	IREN	408	3.9	1.2
8	xAI (own gas turbines)	408 (727)	3.4	1.0 (1.8)
9	Apple	348	2.4	0.6
10	AboutBit	904	0.9	0.6
	Other corporate data centers	449	37	12
	Total of all corporate data centers	462	193	65

Source: Öko-Institut, analysis of the BloombergNEF database combined with EMBER emission factors for 2025

The 10 largest emitters among colocation data centers are listed atTable 4-2. The top 10 colocation data centers have total emissions of approximately 35 Mt CO_2e/a, accounting for 33% of the total emissions from all colocation data centers in 2025. The average CO_2-intensity of computing (CUE) ranges from 329 to 714 and varies by a factor of more than two in some cases. Therefore, the choice of colocation provider for one's own IT operations makes a significant difference in greenhouse gas emissions.

Table 4-2: Top 10 Co-location Data Centers by Greenhouse Gas Emissions in 2025

No.	Co-location data center operator	Average CUE [g CO_2e/kWh_{IT}]	Energy consumption [TWh/a]	Greenhouse gas emissions [Mt CO_2e/a]
1	Digital Realty	329	21	5.2
2	Equinix	419	15	4.7
3	NTT Global Data Centers	524	12	4.6
4	GDS Holdings	713	8	4.4
5	QTS Datacenters	380	14	4.0
6	ChinData Group	714	6	2.9
7	CyrusOne	375	9	2.4
8	Vantage Data Centers	366	8	2.3
9	AirTrunk	624	4	2.3
10	STACK Infrastructure	331	7	1.8
	Other co-location data centers	508	187	71
	Total of all colocation data centers	485	292	105

Source: Öko-Institut, analysis of the BloombergNEF database combined with EMBER emission factors for 2025

5 Ways to reduce greenhouse gas emissions of data centers

The volume of greenhouse gas emissions from data centers is substantial. In 2025, it amounted to at least 170 Mt CO_2e. Five years later, in 2030, this figure is expected to reach at least 313 Mt CO_2e. If all currently announced projects are implemented, global emissions will rise to as much as 529 million metric tons of CO_2-equivalents.

Below, we outline various ways in which data centers emissions can be reduced.

Frugality

An effective mitigation strategy involves limiting computing power requirements. This begins with determining the actual digitalization needs rather than, as is currently the case, pursuing unlimited expansion. A “frugality strategy” encompasses both the elimination of unnecessary digital applications and a cap on data center capacities. This helps avoid rebound effects. Governments, for example, have the option of imposing higher taxes on advertising and curbing addictive services. The four largest hyperscalers account for 45% of data centers emissions (see Figure 4-1) and are subject to high expectations from their shareholders regarding growth and returns. Measures ranging from antitrust law to conversion to public ownership can limit this growth and have a positive impact on climate policy.

Efficiency

Improving energy efficiency aims to reduce energy consumption per computation. Relevant approaches include optimizing software and algorithms, as well as improving utilization and using hardware that is more energy-efficient overall.

Reducing losses in building systems

Minimizing ancillary technical energy consumption, particularly for cooling, ventilation, and power conversion. This is reflected in an improved PUE value. The use of evaporative cooling should not be considered a sustainable alternative, as it leads to increased water consumption.

Lower-carbon electricity mix

The choice of location for a data center has a significant impact on greenhouse gas emissions, depending on the emission factor of the local electricity mix. Operating in countries or regions with a high share of renewable energy and correspondingly lower specific emissions can significantly reduce operational CO_2 emissions. Customers of colocation data centers have the option to consciously choose providers with lower CO_2 emissions.

On-site generation or physically connected electricity procurement

Electricity generation using renewable energy sources that have a physical connection to the data center is also to be considered to reduce emissions. This can be achieved through renewable on-site generation facilities, such as photovoltaic systems or investments in wind turbines, or through the purchase of electricity from a third party via a physical connection. The key factor is that data centers cover their energy needs not through existing but through additional renewable generation facilities that produce electricity at the same time it is consumed.

Recovery of waste heat

The use of waste heat can improve the carbon footprint of data centers if it replaces fossil fuel-based heat generation. This can be reflected using the CUE approach (even though this is not yet provided for in the EN 50600-4-8 standard):

$$CUE = PUE \cdot \left(EF_{electricity} - ERF \cdot EF_{replaced\ fossil-based\ heat}\right) \quad [\text{g } CO_2 \text{ e/kWh}_{IT}]$$

The extent to which usable heat is recovered (ERF = Energy Reuse Factor) and the amount of fossil-based heat that is actually being substituted as a result are decisive for emission reduction. In combination with renewable electricity and high heat output, data centers can even operate in a climate-positive manner, i.e., achieve a CUE of less than 0.

Temporary storage of solar daytime electricity and wind energy

The temporary storage of locally generated solar power or wind energy in battery storage systems makes it possible to use renewable electricity more flexibly over time for data center operations. This allows the share of low-emission self-generation in actual consumption to be increased, even when the data center consumes energy during periods of low sunlight and low wind. In this way, the effective emission factor of the local power supply can be further reduced.

Bibliography

Bauknecht, D.; Müller, B.; Gröger, J.; Heinemann, C.; Seebach, D. (2026): Data centres and flexibility, Study for 4E EDNA. Öko-Institut. Freiburg.

BDEW (2024): Leitfaden Stromkennzeichnung, Umsetzungshilfe für Lieferanten von Strom zu den Bestimmungen über die Stromkennzeichnung (§ 42 Abs. 1 bis 8 EnWG i. V. m. § 79 EEG). Bundesverband der Energie- und Wasserwirtschaft e.V. Online available at https://www.bdew.de/media/documents/241001_Leitfaden_Stromkennzeichnung_2023.pdf, last accessed on 22.05.2026.

BloombergNEF (2026): Data center projects database 1.4.0, This dataset contains the announced, live and under-construction IT capacities for data centers over time. Stand: 01.04.2026. Unter Mitarbeit von Arnold, L. und Daly, M. Bloomberg Finance L.P.

Blum, K. R. (2025): CyrusOne und E.ON geben strategische Partnerschaft bekannt. eon (Ed.). Online available at https://www.eon.com/de/ueber-uns/presse/pressemitteilungen/2025/cyrusone-und-eon-geben-strategische-partnerschaft-bekannt.html, zuletzt aktualisiert am 02.06.2025, last accessed on 26.05.2026.

CNDCP (2025): Climate Neutral Date Centre pact, Self Regulatory Initiative. CNDCP (Ed.). Online available at https://www.climateneutraldatacentre.net/wp-content/uploads/2023/02/221213_Self-Regulatory-Initiative.pdf, last accessed on 22.05.2026.

Ember-Energy (2026): Electricity Data Explorer - Carbon Emissions Intensity. Ember-Energy (Ed.). Online available at https://ember-energy.org/data/electricity-data-explorer/?data=co2_intensity, last accessed on 22.05.2026.

Enerdata (2025): Globales Energie- und Klimastatistik-Jahrbuch 2025, Heimischer Stromverbrauch - Aufschlüsselung nach Ländern. Online available at https://energiestatistik.enerdata.net/strom/strom-heimisches-verbrauch-data.html, last accessed on 22.05.2026.

EPA (2025): eGRID Summary Tables 2023, United States Environmental Protection Agency. Online available at https://www.epa.gov/egrid/summary-data, last accessed on 22.05.2026.

Gröger, J.; Behrens, F.; Gailhofer, P.; Hilbert, I. (2025): Umweltauswirkungen Künstlicher Intelligenz, Auswertung aktueller Trends und Erstellung einer Übersichtsstudie für Greenpeace e.V., Hamburg. Öko-Institut. Online available at https://www.oeko.de/fileadmin/oekodoc/Report_KI_DEU.pdf, last accessed on 22.05.2026.

Gröger, J.; Liu, R. (2021): Green Cloud Computing, Lebenszyklusbasierte Datenerhebung zu Umweltwirkungen des Cloud Computing. Unter Mitarbeit von Stobbe, L.; Druschke, J. und Richter, N. Umweltbundesamt (Ed.). Dessau-Roßlau. Online available at https://www.umweltbundesamt.de/sites/default/files/medien/5750/publikationen/2021-06-17_texte_94-2021_green-cloud-computing.pdf, last accessed on 22.05.2026.

Icha, P.; Lauf, T. (2026): Entwicklung der spezifischen Treibhausgas-Emissionen des deutschen Strommix in den Jahren 1990 - 2025. Umweltbundesamt. Dessau-Roßlau. Online available at https://doi.org/10.60810/openumwelt-8399, last accessed on 22.05.2026.

IEA (2026): Key Questions on Energy and AI. International Energy Agency. IEA (Ed.). Paris. Online available at https://www.iea.org/reports/key-questions-on-energy-and-ai, last accessed on 22.05.2026.

Lauf, T.; Memmler, M.; Schneider, S. (2025): Emissionsbilanz erneuerbarer Energieträger 2023, Bestimmung der vermiedenen Emissionen im Jahr 2023 (Climate Change, 03/2025). Umweltbundesamt. Online available at https://www.umweltbundesamt.de/publikationen/emissionsbilanz-erneuerbarer-energietraeger-2023, last accessed on 22.05.2026.

Murzakulova, Z. (2025): Stand und Entwicklung des Rechenzentrumsstandorts Deutschland, Gutachten im Auftrag des Bundesministeriums für Wirtschaft und Klimaschutz. Deutsche Energie-Agentur GmbH. Online available at https://www.bundeswirtschaftsministerium.de/Redaktion/DE/Publikationen/Technologie/stand-und-entwicklung-des-rechenzentrumsstandorts-deutschland.pdf, last accessed on 22.05.2026.

Open Energy Outlook (2025): Electricity Grid Impacts of Rising Demand from Data Centers and Cryptocurrency Mining Operations. Unter Mitarbeit von Wade, C.; Blackhurst, M.; DeCarolis, J.; Queiroz, A. de; Johnson, J. et al. Online available at https://energy.cmu.edu/_files/documents/electricity-grid-impacts-of-rising-demand-from-data-centers-and-cryptocurrency-mining-operations.pdf, last accessed on 22.05.2026.

Rozier, A. (2026): xAI now has 46 gas turbines without air permits. State officials are ‘evaluating the situation’. In: *Mississippi Today* (11.05.2026), 2026. Online available at https://mississippitoday.org/2026/05/11/xai-46-gas-turbines-no-air-permits/, last accessed on 22.05.2026.

Stobbe, L.; Druschke, J.; Aslan, Tuğana, Proske, Marina; Schulz, A.; Chisolm, C.; Arnold-Keifer, S.; Thesen, M.; Nissen, N. F. (2025): Strombedarf und Carbon Footprint der IKT in Deutschland 2010 - 2036. Fraunhofer-Institut für Zuverlässigkeit und Mikrointegration. Berlin. Online available at https://www.izm.fraunhofer.de/content/dam/izm/de/documents/Abteilungen/Environmental_Reliability_Engineering/Projekte/Green-ICT-@-FMD-IKT-Studie-Deutschland.pdf.

Synergy Research Group (2025): Hyperscale Operators to Account for 67% of all Data Center Capacity by 2031. Online available at https://www.srgresearch.com/articles/hyperscale-operators-to-account-for-67-of-all-data-center-capacity-by-2031, last accessed on 22.05.2026.

van Osdol, N.; Hughes, T. (2026): Bring Your Own Power (BYOP), A deep dive on how data center developers plan to power their projects, www.keepcool.co. Online available at https://www.keepcool.co/p/bring-your-own-power-byop, last accessed on 22.05.2026.

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