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Decoding Europe's Data Centre Landscape: An Analysis based on the EU EED DC Dashboard

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Abstract

The rapid expansion of digital infrastructure has made data centres a focal point of European energy and climate policy. Under the recast Energy Efficiency Directive (EED), the European Union established a public Data Centre Registry and Dashboard to enforce unprecedented transparency on energy and environmental related performance. However, initial releases of these official datasets present substantial challenges regarding data completeness and reporting anomalies, limiting their immediate usability for empirical policy assessment. This paper presents a comprehensive analysis and systematic refinement of the initial published dataset. We developed an automated data-processing workstream to validate registry disclosures, filter statistical outliers, and resolve data gaps by recalculating core metrics, including calculated average Power Usage Effectiveness (PUE), utilization rates, and data centre capacity relative to national economic indicators. Our findings uncover significant regional variations in energy efficiency and infrastructure density and utilisation across Europe, characterized by a sharp geographic efficiency gradient favoring northern member states. Furthermore, evaluating the framework's effectiveness reveals structural data quality issues, yielding an estimated overall EU data centre coverage rate of just 38 % alongside critical reporting anomalies, such as theoretical utilization rates exceeding 100 % in select member states. Ultimately, this study establishes a highly curated baseline of the current European digital infrastructure landscape and provides a refined, reliable dataset to track the sector's trajectory toward net-zero goals.

Keywords: Energy Efficiency Directive, Data Centre Reporting, Data Analysis, Sustainable Computing, Power Usage Effectiveness, Water Usage Effectiveness, Energy Reuse Factor

1 Introduction

The entry into force of the "Energy Efficiency Directive" (EED) is intended to help improve energy efficiency in the European Union [European Commission, 2026b]. Across all sectors, data centres are becoming an increasingly significant consumer of electrical energy, having required around 485 TW h worldwide by 2025 [International Energy Agency, 2026]. In 2024, only 15 % of global data centre capacity was located in Europe [Jacamon et al., 2025]. Due to their size, pace of development and geographical concentration, data centres pose a challenge both for the electricity grid, for the regulator as well as for the transition to a climate-neutral EU [Jacamon et al., 2025, European Commission, 2026b].

Consequently, Article 12 of the EED contains a separate section devoted solely to data centres [European Union, 2023]. Accordingly, all data centre operators in the EU with an installed IT capacity of at least 500 kW per site are required to publish a fixed set of information. The Commission Delegated Regulation (EU) 2024/1364 sets out all relevant terms, the information to be reported, key performance indicators, the formulas for calculating sustainability indicators, and the information to be published in the European database [European Union, 2024].

On the basis of the annual reportings, a European database containing aggregated data was established and made available to the public. The EU Commission will analyse the reported data to submit a report and propose new laws establishing mandatory minimum energy efficiency standards

and a net-zero transition timeline that even existing data centres must meet. This database is primarily intended to be used for the establishment of a rating scheme [Commision, 2026]. In contrast, Germany has already established requirements for the maximum permissible "Power Usage Effectiveness" (PUE) through its implementation of the EED [ene, 2023].

To date, there has been no freely available systematic collection of data on the key characteristics of various power sizes and operational models for data centres. The first version of the public dashboard was released in April 2026 [European Commission, 2026a]. As part of this paper, a methodology was developed that automatically extracts all available data from this database, validates it, links it to other data sources, and calculates additional metrics. The aim of this approach is to gain a better understanding of the interrelationships between sustainability parameters across different countries, the extent to which the register covers data centres that may be subject to reporting requirements, and trends over time.

2 Data and Methodology

This section begins by describing the data sources used and their intended purpose in Section 2.1. In particular, with regard to the primary source, the EED DC Dashboard, the method used to extract the raw data is explained. The steps taken to integrate further data sources and the calculation of additional metrics are then outlined in Section 2.2. Finally, the methods used to validate the published raw data are explained in Section 2.3.

2.1 Data Source

In the *EU Datacentre Dashboard* [European Commission, 2026a], the raw data is presented in tabular form, with three different worksheets: *Category*, *Type* and *Country*. Table 1 lists the characteristics of the various data centre categories. According to the EU, the type of data centre can take the following values: *enterprise*, *colocation* and *co-hosting* [European Union, 2024]. The relevant definitions can be found in Article 2 of the Delegated Regulation 2024/1364 [European Union, 2024].

Table 1 Overview of the definitions of the different categories of data centres [European Union, 2024].

Category	IT Power range	Unit
very small	100 - 500	kW
small	500 - 1000	kW
medium size	1 - 2	MW
large	2 - 10	MW
very large	> 10	MW

The first two worksheets of the dashboard include the four key sustainability metrics – PUE, WUE (Water Usage Effectiveness), REF (Renewable Energy Factor) and ERF (Energy Reuse Factor) – as weighted averages based on the total energy consumption, as well as the number of reporting data centres. In the first case, the category indicates the size of the data centre based on its "Information Technology" (IT) capacity, whereas in the second case, the type of operator is specified. The final worksheet contains significantly more information, including the total energy consumption for IT and the entire data centre, as well as the installed IT capacity for each country. In all three cases, it is possible to filter by the year of the report and by country. Currently, 19 out of 26 EU countries with reporting obligations and the years 2023 and 2024 are available for selection. At present, there is no export function that allows all the raw data for every possible combination to be extracted. For this purpose, a Python-based automation script was created to systematically export all possible combinations. This enables the database to be updated efficiently for the next reporting periods.

Table 2 lists further data sources used, including the date of the last update and the purpose for which they are used, with the source specified.

The Data Centre Map [DCM, 2026] provides a list of known data centres, and the filter function makes it possible to select the regions of Eastern Europe and Western Europe. Both lists can be saved and merged. It is not known what size and type of data centre is included in the stated number. Nevertheless, a comparison with the reported data can provide an initial estimate of how many of the data centres that may be required to report have actually done so. However, the advantage of this data source is that it provides centralised information for all European countries.

Table 2 Data source for analysis and integration with other areas.

Data source	Last updated	Purpose	Reference
Data Centre Dashboard	2026-04-22	Primary data source	[European Commission, 2026a]
Data Center Map	2026	Share of registered data centres	[DCM, 2026]
Electricity	2026-04-28	Share of electricity consumption	[Eurostat, 2026b]
Gross domestic product	2026-05-18	Economic performance	[Eurostat, 2026a]
Cooling degree days	2026-05-08	Cooling demand	[Eurostat, 2026c]
Population	2026-04-30	Population	[Eurostat, 2026d]

Eurostat's statistical data on electricity consumption [Eurostat, 2026b] and "Gross Domestic Product" (GDP) [Eurostat, 2026a] for various years and countries are available in table format and can be downloaded with minimal effort. The data is available up to 2024 and, in some cases, 2025. These official statistics can help to determine the share of energy consumption accounted for by data centres in the respective countries. In addition, the ratio of IT capacity to national productivity can also be calculated.

The three additional data sources can only be meaningfully combined with the country data from the dashboard, for which the country code is used as a concatenation.

To automatically extract the raw data from the database, the `playwright.sync_api` module in Python is used for browser automation. This automatically selects the three sheets in sequence and systematically sets the filter options for year and country. The embedded table data is then read and saved together with the row and column headings. The selected filter criteria are also saved as metadata so that verifications can be made if required.

2.2 Data Preprocessing and Metrics

During the subsequent data processing, all information from the various data sources is consolidated. This applies only to the raw data for the country-specific files. Therefore, the country name is used as the reference key for the merging of data. In the case of the other two worksheets (category and type) from the dashboard, all exported files containing the raw data are merged into a single file and supplemented with the country name and the year.

With regard to the countries, additional custom metrics are then calculated. This includes calculating the PUE, as no data is displayed in the dashboard for certain cases. This applies to countries that have less than 3 data centres and where, for data protection reasons, no further details are provided [European Union, 2024]. Independent calculations can be carried out based on the total energy consumption data provided for the data centre (E_{DC}) and information technology (E_{IT}) in each case. However, the same cannot be done for the WUE, since the absolute water consumption data has not been published. To distinguish this aggregated metric from the weighted average KPIs provided in the EED dashboard, this paper introduces the term *PUE (calculated average)* for values derived through this methodology.

$$PUE\,[-] = \frac{E_{DC}\,[\mathrm{kW\,h}]}{E_{IT}\,[\mathrm{kW\,h}]} \tag{1}$$

In addition, the number of of full-load operation hours (t_{fl}) for IT systems and the utilization (u_{IT}) of the IT infrastructure are calculated on the basis of the reported installed IT capacity (P_{IT}) and IT energy consumption (E_{IT}). For the year 2024, it is taken into account that it was a leap year.

$$t_{fl}\,[\mathrm{h}] = \frac{E_{IT}\,[\mathrm{kW\,h}]}{P_{IT}\,[\mathrm{kW}]} \tag{2}$$

$$u_{IT}\,[\%] = \frac{t_{fl}\,[\mathrm{h}]}{t_a\,[\mathrm{h}]} \cdot 100 \tag{3}$$

$$t_a = \begin{cases} 8760\,\mathrm{h} & \text{regular year (365 days)} \\ 8784\,\mathrm{h} & \text{leap year (366 days)} \end{cases} \tag{4}$$

The additional data sources are used for the calculation of the following metrics. This includes estimating the coverage ratio (C_c) of reporting data centres (R_c) to the known number of data centres (N_c) in each country ($_c$).

$$C_c\,[\%] = \frac{R_c\,[-]}{N_c\,[-]} \cdot 100 \tag{5}$$

In addition, the proportion of energy consumption accounted for by IT or the whole data centre ($E_{i,c}$) for each respective assessment boundary ($_i$) and country ($_c$) is calculated in relation to the total electricity consumption ($E_{\mathrm{el},c}$) of the respective countries.

$$S_{i,c}\,[\%] = \frac{E_{i,c}\,[\mathrm{kW\,h}]}{E_{\mathrm{el},c}\,[\mathrm{kW\,h}]} \cdot 100 \tag{6}$$

Energy and power demand ($X_{i,c}$) are normalized by gross domestic product (G_c) and population (N_c), yielding intensity ($I_{i,c}$) and per capita ($K_{i,c}$) indicators.

$$I_{i,c} = \frac{X_{i,c}}{G_c} \qquad K_{i,c} = \frac{X_{i,c}}{N_c} \tag{7}$$

2.3 Quality Assessment

In order to validate the raw data and to assess the quality of the reported data, the limit values for the parameters listed in Table 3 were defined. If a parameter falls outside the threshold, the relevant value is flagged and checked manually. If it is a sustainability KPI (like PUE, WUE etc.), this value will no longer be used in subsequent processes. If the utilization rate exceeds 100 %, the entire dataset will no longer be taken into account, as it must be assumed that part or possibly all of the dataset is incorrect. To further contextualise the data and results, data from literature are used.

Table 3 Overview of the parameters considered for validation and their limit values.

Parameter	Threshold for validation
IT Load [%]	> 100
PUE [-]	≤ 1.0
REF [-]	> 1.0
ERF [-]	> 1.0

3 Results

This section presents the empirical findings derived from the processed and validated *EED DC Dashboard* dataset. The results are structured into four thematic subsections: an overview of the current data centre landscape across the European Union (Section 3.1), an analysis of reported energy and resource efficiency metrics (Section 3.2), an assessment of augmented economic indicators (Section 3.3), and a discussion of data quality and reporting coverage rate (Section 3.4). Unless otherwise stated, all analyses are based on the datasets listed in Table 2 for the reporting years 2023 and 2024. In this study, the analysis focuses primarily on country-specific data and the reporting year 2024, as datasets for 2023 have a lower robustness.

3.1 Status Quo of Europe's Data Centres

Figure 1 shows the composition of the reported data centre landscape across the five largest contributors to the EED registry in 2024, determined by the number of reported date centres. The share of each country is then segmented by data centre category, based on the installed IT power demand. With 370 reporting data centres representing 46.6 % of data centres listed in the EU database, Germany accounts for the largest share of data centres in Europe, followed by France with 152 (19.1 %) and the remaining countries aggregated under *Others* contributing 134 facilities (16.9 %). The Netherlands, Poland and Spain each reported a comparatively smaller absolute number, with 61, 39 and 38 data centres, respectively.

Within each country, the distribution across the data centre categories reveals structural differences. Germany's inventory is comparatively balanced, with no single category exceeding 29 % and more than half of all reported facilities falling within the 1 MW to 10 MW range. France and Spain, by contrast, show a pronounced concentration of 39.5 % in the large category (2 MW to 10 MW). For France alone, 50 % of reporting data centres declare an installed IT power demand of 2 MW or more.

These structural differences are not merely descriptive. The size composition of a national reporting population constitutes a potential confounding factor for country-level efficiency aggregates, since operational overhead tend to reduce and cooling efficiency often improve with installed

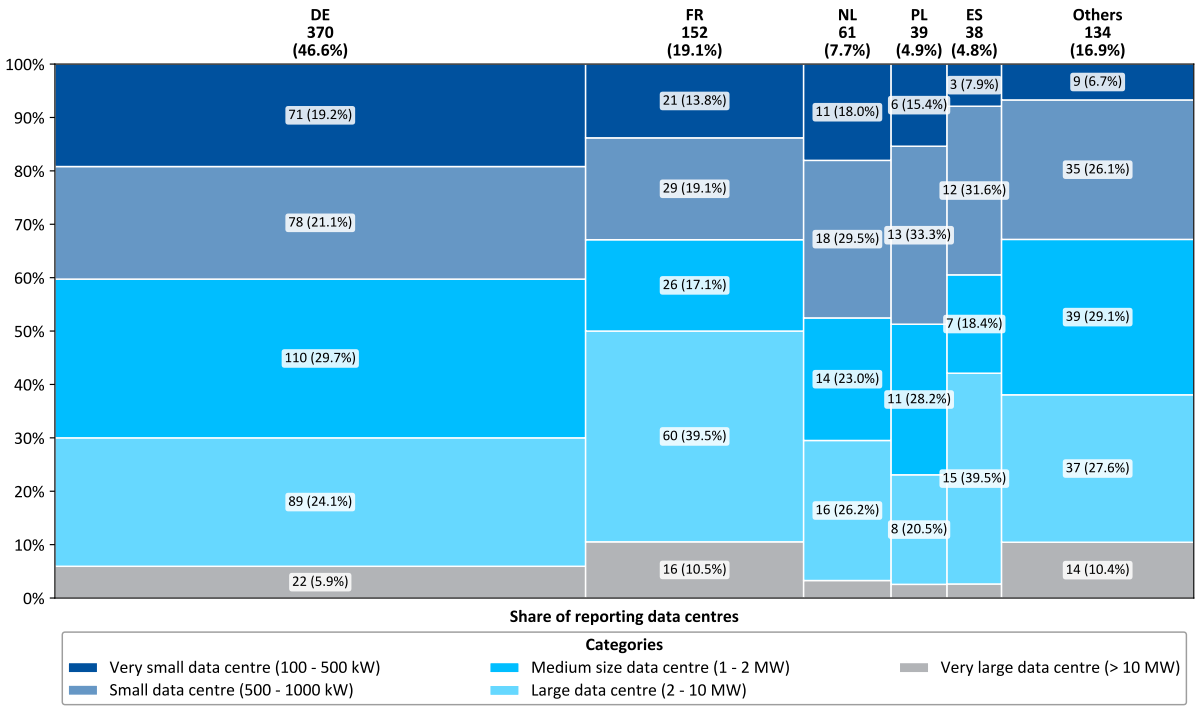


Fig. 1 Share and number of reporting data centres by country and data centre category in 2024, featuring the top five countries by reported number of date centres and an aggregated category for remaining reporting countries.

IT capacity [Davis, 2024]. Countries whose inventories are skewed towards larger or hyperscale-adjacent facilities may therefore exhibit structurally more favourable energy and water consumption profiles than those dominated by smaller enterprise data centres, independent of genuine differences in operational practice. This structural heterogeneity is considered when interpreting the efficiency metrics presented in Section 3.2.

3.2 Energy and Resource Efficiency Metrics

Figures 2-6 characterize the energy and resource efficiency of European data centres, first through a geographic distribution of absolute metric values in 2024 (Figures 2 and 3), and subsequently through a focused multi-indicator and year-over-year comparison for 2023 and 2024. For an initial macro-level overview, Table 4 aggregates the weighted efficiency metrics across the broader European landscape for both reporting years. At a glance, these baseline figures indicate a general improvement in primary efficiency and sustainability indicators, marked by enhanced energy and water efficiency alongside an increased share of renewable energy, even though the Energy Reuse Factor (ERF) shows a slight decline. While this table serves as a foundational reference point, a more granular interpretation and comprehensive discussion of these year-over-year dynamics are provided in the dedicated analyses later in this section.

Table 4 Aggregated year-over-year comparison of sustainability indicators for European data centres based on the total energy consumption(2023–2024).

Parameter	2023	2024	Unit
PUE	1.40	1.36	-
WUE	0.387	0.314	L/kWh
ERF	0.0231	0.0199	-
REF	0.84	0.89	-

To enable a targeted evaluation of the most impactful regions, this study defines a focus group

comprising the five countries with the highest reported installed IT power demand for the following analyses (Figures 4–6): Germany (DE), France (FR), the Netherlands (NL), Finland (FI), and Sweden (SE). For this selection of countries, an overview of the key raw data and self-calculated indicators has been compiled in Table A1.

Besides, it should be noted, that Denmark, which ranks among the top five countries by reported installed IT power demand was excluded from all subsequent analyses due to data quality constraints. Specifically, their calculated IT load (Equation (3)) exceeded the predefined threshold of 100 %, reaching 140.6 %. As explained in Section 2.3, an utilization rate surpassing this theoretical maximum indicates fundamental data reporting anomalies or inconsistencies within the raw datasets, necessitating the complete removal of these countries from the validated results to prevent statistical distortion. Malta was also excluded for the same reason with an utilization rate of 101.3 %.

A. Geographic Distribution of Power Usage Effectiveness

Figure 2 shows the spatial distribution of the calculated average PUE across EU member states for the reporting year 2024, computed using Equation (1). Finland achieves the lowest reported PUE of 1.14, setting the current performance benchmark within the EED data set, while Cyprus records the highest calculated value at 1.77.

A pronounced geographic gradient is observable: Northern European countries, including Finland and Sweden, consistently report lower PUE values, whereas several southern and eastern member states exhibit higher values where date are available. This north–south gradient reflects the effect of cooler ambient temperatures increasing the potential of free cooling and therefore reducing the need for additional mechanical cooling. However, facility size and age are likely additional determinants, as newer and larger data centres tend to benefit from more advanced cooling infrastructure. Smaller facilities predominantly rely on direct expansion systems, whereas larger installations more frequently employ airside economizers, or IT liquid cooling solutions. Utilization patterns constitute a further contributing factor: hyperscale facilities operate at substantially higher average server utilization rates than colocation or smaller data centres, thereby achieving lower energy overhead per unit of useful compute output and, consequently, lower effective PUE at the workload level [Shehabi et al., 2024].

Simulated PUE ranges indicate that these latter system classes achieve lower values than direct expansion under equivalent conditions, and that larger facilities tend to achieve lower PUE values even when deploying the same cooling system type [Shehabi et al., 2024]. This structural effect is of growing relevance. in Germany, for instance, capacity growth has been driven predominantly by the construction of large-scale facilities, with installations exceeding 5 MW of installed IT capacity accounting for more than 50 % of total national data centre capacity by 2025 [Hintemann and Hinterholzer, 2025].

In Sweden, 80 % of reported data centres in 2024 declared an installed IT power of 2 MW or more, while in Finland 25 of 28 reporting facilities exceeded 1 MW, which may contribute to both countries' favourable PUE values beyond the effect of favourable climate conditions alone. In contrast, in Portugal 87.5 % of reporting facilities declared an installed IT power demand of at most 2 MW, and in Spain 58 % of facilities fell below this threshold, suggesting a predominance of smaller installations that may structurally limit achievable PUE values independently of climate.

Against this backdrop, the weighted average PUE of EED-reporting facilities stands at 1.36 in 2024 and 1.40 in 2023 (Table 4). Those values compare favourably with the Uptime Institute's global averages of 1.56 (2024) and 1.58 (2023) [Uptime Institut, 2025]. This gap warrants cautious interpretation, however, as it may partly reflect the compositional bias noted above rather than a genuine European efficiency advantage. An earlier Uptime study, on the other hand, showed that, on average, Europe tends to be the most efficient compared with other regions of the world [Lawrence, 2020].

For Germany for example, a preliminary initial analysis of the reported data prior to its official publication revealed an average weighted PUE of 1.39 [European Commission et al., 2025], although other sources cite a PUE of 1.46 for 2024 [Hintemann and Hinterholzer, 2025]. The scale is broadly consistent, although differences depend primarily on the underlying data sources and the methods

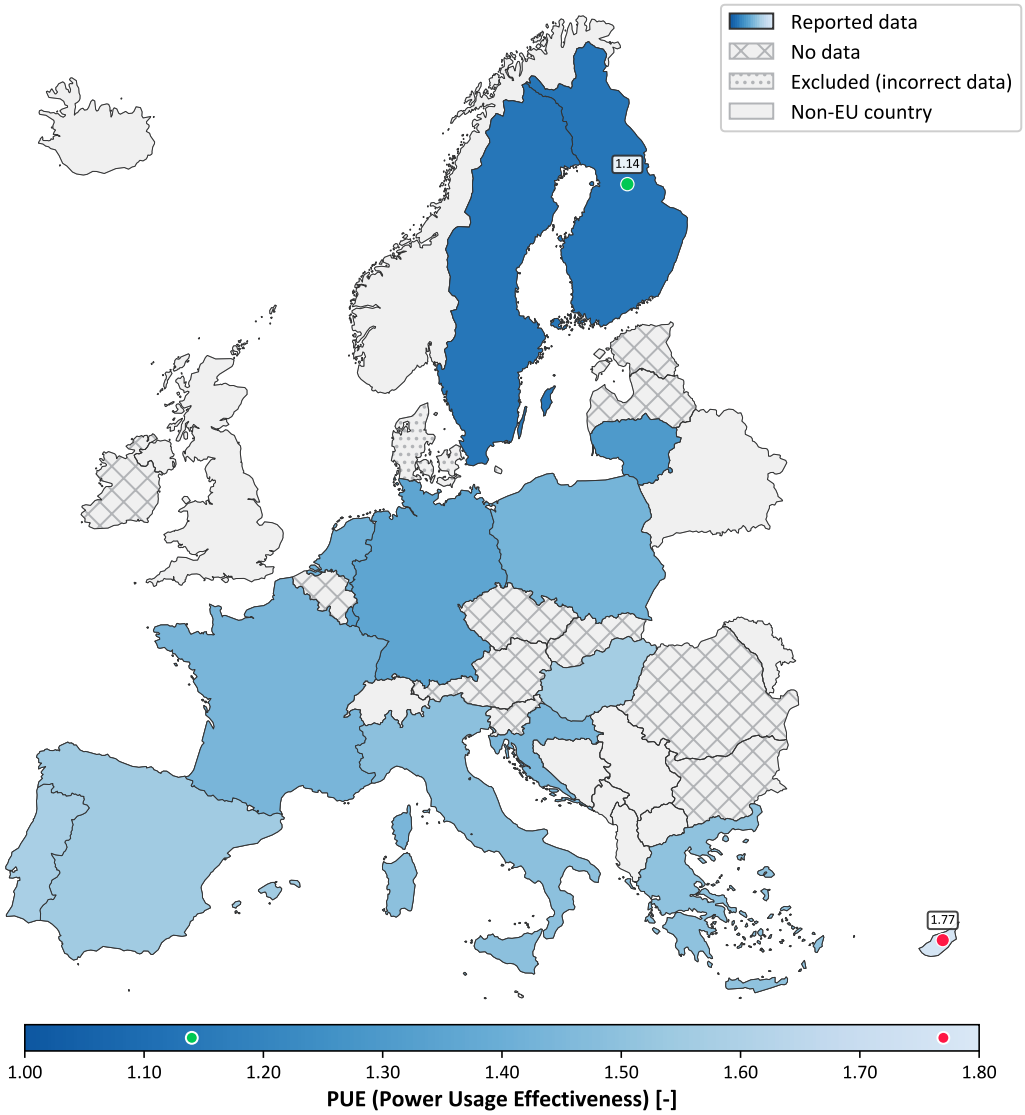


Fig. 2 Geographic distribution of calculated average Power Usage Effectiveness (PUE) across the EU in 2024, computed as the ratio of reported total data centre energy consumption to IT equipment energy demand, with green and red indicators highlighting the best value in Finland and the worst value in Cyprus, respectively.

used, as well as on the size of the covered data centres.

Crucially, the substantial proportion of member states for which no weighted averaged data could be reported limits the geographic representativeness of any EU-level aggregate. To partially mitigate this constraint, Figure 2 draws on the independently calculated average PUE (Equation (1)) rather than the dashboard-provided weighted average, which is withheld for countries reporting fewer than three data centres under Commission Delegated Regulation (EU) 2024/1364 [European Union, 2024]. This data protection threshold structurally biases aggregate assessments toward larger markets. Computing PUE directly from reported total and IT energy consumption extends coverage to member states that would otherwise remain absent from the geographic analysis, yielding a more complete, if still partial, picture of the European data centre efficiency landscape.

B. Geographic Distribution of Water Usage Effectiveness

Figure 3 presents the geographic distribution of the weighted average WUE across reporting EU member states in 2024. Hungary records the lowest WUE at 0.01 L/kWh, the Netherlands reports the highest value at 0.877 L/kWh. Although northern member states such as Finland and Sweden also record comparatively low WUE values, no north–south gradient analogous to that observed for PUE (Figure 2) is discernible.

This suggests that cooling technology choices, in particular the prevalence of evaporative or water-cooled systems, constitute a more significant determinant of water consumption intensity than climatic conditions alone. Notably, the Netherlands, which performs comparatively well on PUE, simultaneously exhibits the highest reported WUE within the dataset, highlighting an inherent tension between energy and water efficiency that arises from certain cooling strategies. This trade-off carries direct policy implications: regulation focused exclusively on PUE minimization may inadvertently incentivise the adoption of water-intensive cooling technologies, underscoring the necessity of a multi-indicator framework, as mandated by the EED, for a comprehensive assessment of data centre environmental performance [Patterson et al., 2011].

The EU-level weighted average WUE improved from 0.387 L/kWh in 2023 to 0.314 L/kWh in 2024 based on the EED reporting data analysed in this study (Table 4). However, estimates from other sources diverge: the EUDCA reports a higher value of 0.44 L/kWh for 2024 [EUDCA, 2026], and the European Commission's first technical assessment of EED data centre reporting yields an EU average of 0.58 L/kWh for 2023 [European Commission et al., 2025]. According to the EUDCA, 55 % of its members reported to have achieved the WUE target of a maximum of 0.4 L/kWh [EUDCA, 2026]. It should be noted that the 0.4 L/kWh threshold reported by EUDCA functions as an illustrative reference value rather than a uniform compliance threshold. Under the Climate Neutral Data Centre Pact (CNDCP), a voluntary, industry-led self-regulatory initiative developed with the involvement of the European Commission, individual signatories set facility-specific WUE targets derived from a common formula that adjusts for local climate, water stress levels, and water type [Climate Neutral Data Center Pact, 2024]. These aggregate-level discrepancies likely reflect differences in reporting population, weighting methodology, and the treatment of non-reporting facilities, and underscore the interpretive caution warranted when comparing aggregate WUE figures across sources.

By comparison, the study carried out by a project consortium led by Borderstep found a minimum value of 0.07 L/kWh in Finland and a maximum value of 1.28 L/kWh in Belgium. For Germany, a slightly worse WUE is reported here, standing at 0.65 L/kWh rather than 0.486 L/kWh [European Commission et al., 2025].

C. Multi-Indicator Efficiency Profiles

Figure 4 provides a multi-indicator comparison of the four EED sustainability KPIs: PUE, WUE, REF and ERF. The radar chart employs a normalized rating scale, based on the percentage score achieved in each category, where higher values uniformly indicate better performance across all four dimensions. Since lower values of PUE and WUE correspond to greater efficiency, the axes for those two indicators have been inverted. Moving outward along these axes reflects a decreasing actual value, yet an increasing performance score. Where applicable, a score of 100 % corresponds to the theoretical real-world optimum of each indicator. An exception is made for ERF, where the optimum was set to 0.1 in accordance with the unit of magnitude of the reported values.

The efficiency profiles in Figure 4 reveal notable differences in sustainability performance across the five countries. Finland achieves the highest scores across all four KPI dimensions, reflecting a combination of favourable climatic conditions, a comparatively high share of renewable electricity use, and advanced data centre infrastructure [Eurostat, 2026e, EUDCA, 2026]. Additionally, Finland leverages its extensive district heating networks to systematically repurpose the generated waste heat, which substantially improves the overall energy efficiency and resource integration of its facilities [FDCA, 2025]. Sweden similarly performs strongly on PUE and REF, consistent with its renewable energy mix, though it does not match Finland across all dimensions.

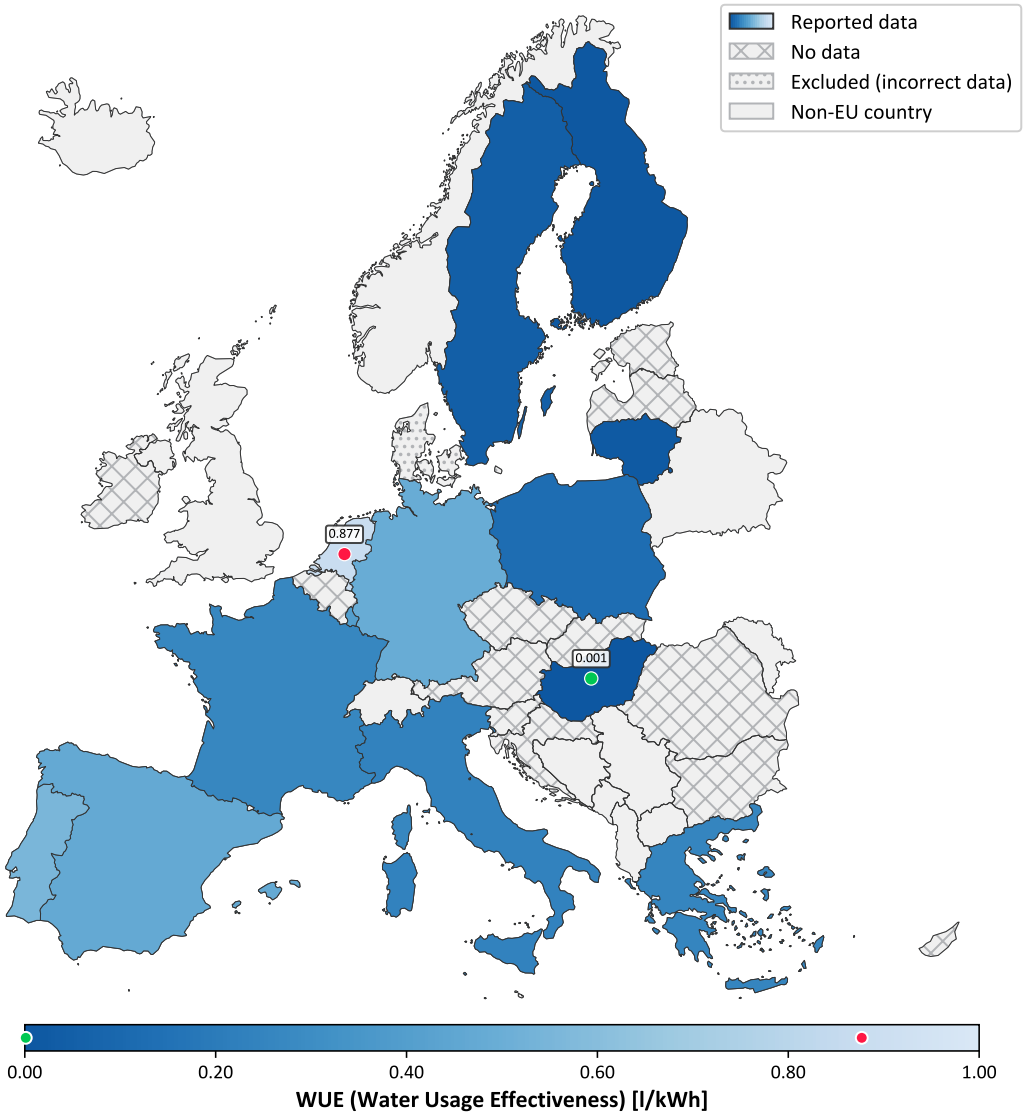


Fig. 3 Geographic distribution of weighted average Water Usage Effectiveness (WUE) across the EU in 2024, with green and red indicators highlighting the best value in Hungary and the worst value in the Netherlands, respectively.

The Netherlands scores competitively on PUE relative to the other countries in this group, yet exhibits the weakest on WUE and REF performance. Germany and France occupy intermediate positions across most dimensions, with neither country achieving top performance on any single indicator. When comparing France and Germany, a difference between PUE and WUE is evident. Whilst France features a better WUE, Germany demonstrates a better PUE. It appears, that Germany's enhanced PUE comes at the expense of its WUE, driven by higher water consumption. Yet the cooling degree days in France are three times higher than in Germany and would require greater effort in terms of cooling.

The differences in PUE, on the other hand, are primarily influenced by the varying climatic conditions and the significant difference in cooling degree days [Eurostat, 2026c]. The differences in the share of renewable energy are a direct consequence of local electricity generation. The northern countries, in particular, have low specific CO_2 emissions from electricity generation, due to a high share of renewable energy and the

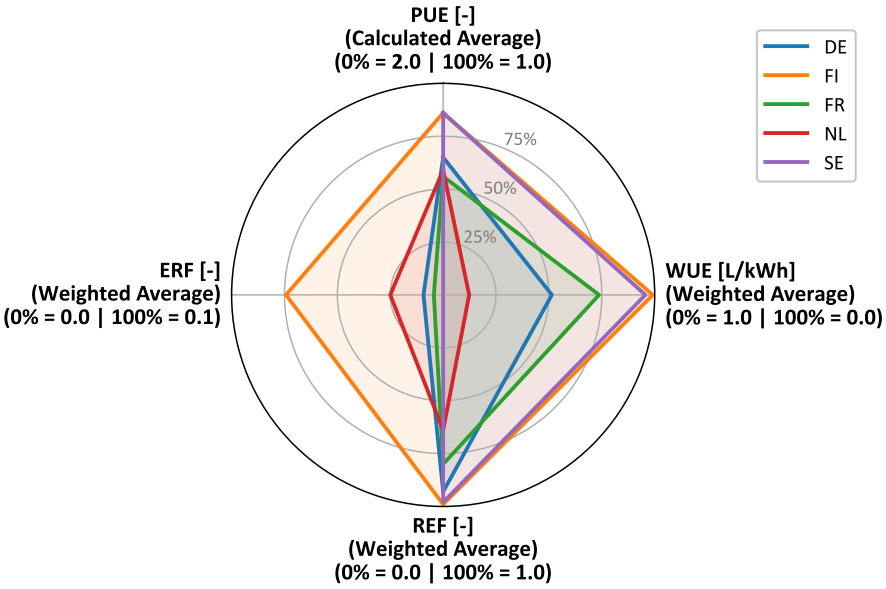


Fig. 4 Efficiency profile of key data centre sustainability indicators (PUE, WUE, REF and ERF) in Europe utilizing standardized ratings to compare multi-criteria environmental performance, featuring the top five countries by reported installed IT power demand in 2024.

use of nuclear power [Eurostat, 2026e]. The fact that waste heat is utilised to a particularly significant extent in Finland is a consequence of the widespread use of district heating networks. In contrast, this is not so pronounced in Germany yet. However, much like in Finland, there is also significant waste heat utilisation in Sweden, although this is not apparent from this database [Ott and Radgen, 2024]. It is possible that data centres that utilise waste heat are particularly lacking here. The low figure for the ERF is primarily due to the fact that only a fraction of existing data centres have the capacity to extract waste heat in the first place, let alone actually utilize it effectively [Ott and Radgen, 2024].

D. Year-on-Year Development of PUE and WUE

Figure 5 and 6 present the year-on-year development of calculated average PUE and weighted average WUE, respectively, for the five focus countries across the 2023 and 2024 reporting cycles. Both figures displaying the country averages for each year alongside the relative inter-annual change, thereby enabling direct assessment of short-term dynamics. Table 5 lists the number of the reporting data centres in 2023 and 2024, as well as their relative annual change. The same is shown for the installed IT power demand.

In some cases, the changes between years for both parameters were within the same range for individual countries (FR, NL). However, there are cases where the reported number (DE) or the IT power (FI, SE) has increased more significantly. This may be due to late registrations or other forms of expansion relating to the capacity of the new data centres. As regards Germany, the estimated installed IT capacity in 2024 was 2730 MW, which corresponds almost exactly to the reported figure, with a deviation of 6.6 %. [Rohleder, 2024].

D1 Year-on-Year Development of PUE

The year-on-year dynamic of the calculated average PUE between 2023 and 2024 reveals highly differentiated national trajectories across the focus group (Figure 5). While Finland presents a static baseline maintaining its highly efficient PUE level (0.0 %), France (−2.0 %), Germany (−0.7 %), and Sweden (−3.4 %) record visible efficiency gains. In contrast, the Netherlands exhibits a deterioration in performance, with its average PUE increasing by 2.9 %.

To adequately interpret these shifts, they must be cross-referenced with the structural inventory

Table 5 Selected country comparison of the number of reported data centres between 2023 and 2024, including the calculated relative annual changes, as well as their installed IT power demand.

Parameter	Unit	DE	FI	FR	NL	SE
Number of Reported Data Centres						
2023	-	314	23	121	44	6
2024	-	370	28	152	61	10
Relative Year-on-Year Change	%	+17.8	+21.7	+25.6	+38.6	+66.6
Installed IT Power Demand						
2023	MW	2440	182	513	92	116
2024	MW	2562	307	631	124	350
Relative Year-on-Year Change	%	+5.0	+68.7	+23.0	+34.8	+201.7

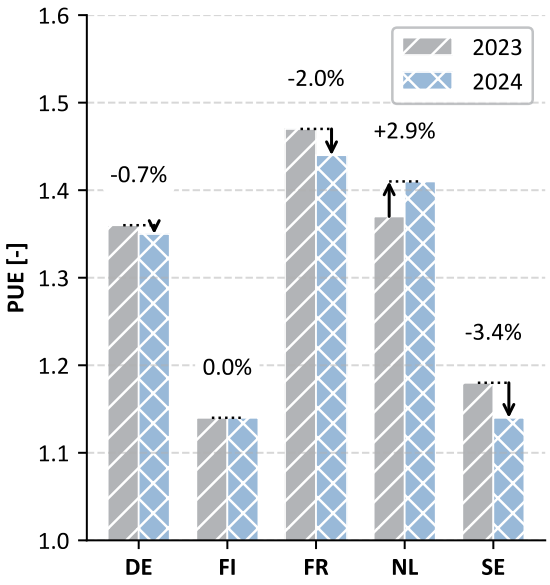


Fig. 5 Calculated average Power Usage Effectiveness (PUE) by country in 2023 and 2024 including the relative annual change, featuring the top five countries by reported installed IT power demand.

dynamics recorded in Table 5. A critical explanatory factor for the observed fluctuations is the changing scale and composition of the national reporting populations. These macro-level adjustments do not necessarily reflect physical optimization or degradation within existing facilities, but may rather stem from shifts in the reporting population, whereby data centres with differing efficiency profiles entered or exited the dataset between reporting cycles.

For instance, Sweden's profound PUE improvement (−3.4 %) is accompanied by an unprecedented surge (201.7 %) in reported installed IT power demand, climbing from 116 MW in 2023 to 350 MW in 2024. This implies a influx of newly constructed, highly advanced large-scale or hyperscale infrastructure whose low PUE values reduced the national aggregate. A parallel, though less pronounced, trend is observable in Finland, where a 68.7 % capacity expansion (reaching 307 MW in 2024) helped secure its benchmark position against potential operational volatility.

Conversely, the negative trajectory of the Netherlands (2.9 % PUE increase) emphasises a reverse compositional effect, driven by a structural shift toward smaller, less efficient facilities. A granular review of the national reporting cohort between cycles reveals a disproportionate expansion in low- and medium-capacity registrations: while facilities with an installed IT power demand of 2 MW or less (comprising *very small*, *small*, and *medium* data centres) accounted for 59.1 % of the sample in 2023, this proportion grew to 70.5 % in 2024. This increase is largely driven by the smaller segments, where "very small" and "small" registrations rose from 7 and 13 in 2023 to 11 and 18 in 2024, respectively. Because smaller data centre topologies inherently struggle to achieve the economies of scale required for advanced cooling efficiency and structural overhead optimization [Shehabi et al., 2024], this rising density of lower-tier installations artificially inflated the national average PUE. Alternatively, highly efficient larger facilities that reported in 2023 may have failed to comply in 2024, further compounding this statistical degradation.

Germany's marginal optimization (−0.7 %) aligns with a stable, mature baseline, characterized by a modest 5 % growth in reported IT

capacity up to 2562 MW. This highlights that in established markets with an expansive reporting base, infrastructural inertia and statistical smoothing can mitigate the impact of individual data centre entries or exits.

D2 Year-on-Year Development of WUE

In contrast to PUE, the inter-annual changes in the reported weighted average WUE are more volatile (Figure 6). Sweden records the most pronounced improvement at −62.1 %, whereas the Netherlands exhibits the sharpest deterioration at 63.0 %. Finland and France also show marked increases in water intensity of 28.6 % and 21.2 %, respectively, while Germany reports a moderate improvement of −11.8 %.

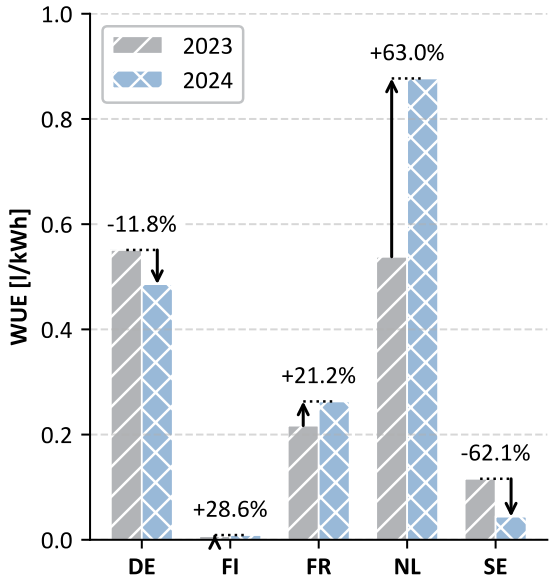


Fig. 6 Weighted average Water Usage Effectiveness (WUE) by country in 2023 and 2024 including the relative annual change, featuring the top five countries by reported installed IT power demand.

These substantial fluctuations reflect that water consumption intensity is highly sensitive to facility-level cooling configurations and operational decisions rather than to aggregate IT capacity expansion alone. The drastic WUE reduction in Sweden, occurring alongside its unprecedented 201.7 % surge in reported IT capacity (see Table 5), reinforces the hypothesis that the newly registered infrastructure consists predominantly of advanced facilities with dry or adiabatic cooling. Conversely, the concurrent 63.0 % WUE deterioration and 2.9 % PUE degradation in the Netherlands suggest an increased reliance on evaporative cooling systems or structural shifts within the reporting population.

This multi-indicator variance confirms the trade-off noted in Section 3.2: when data centres adjust cooling infrastructure to protect energy metrics, water intensity often reacts volatile. Furthermore, the decoupling of indicator trajectories from capacity growth (Table 5) further implies that the early EED reporting cycles still exhibit data collection gaps in water monitoring. Since metering water consumption in chilled-water loops and cooling is less standardized than electrical sub-metering, a portion of the observed inter-annual volatility likely reflects evolving reporting practices and late-stage corrections by operators rather than purely physical changes in environmental performance [Privette et al., 2026]. Climatic variation can largely be ruled out as a confounding driver, as cooling degree days remained broadly stable across the reporting periods, with France representing the sole exception, recording a decrease from 83 to 61 cooling degree days between 2023 and 2024 [Eurostat, 2026b].

Any directional movement across a single annual reporting cycle must nonetheless be interpreted with caution, as it remains premature to characterize observed changes as established trends. Reported shifts may reflect genuine operational improvements, advances in data quality, or changes in the composition of the reporting population, meaning that different sets of facilities contributed to the weighted average in 2023 versus 2024 rather than any physical efficiency adjustments occurring, as evidenced by the inventory dynamics documented in Tables 5.

3.3 Dataset Augmentation

The ratio of reported installed IT power demand to national GDP is represented in Figure 7, calculated as an economic intensity indicator using Equation (7), enabling a comparison of data centre infrastructure density relative to the broader economic output of each country. Therefore, it captures a dimension not visible from sustainability KPIs alone, namely the pace at which

digital infrastructure is expanding relative to national economic activity. Finland exhibits the highest absolute ratio in 2024, followed by Sweden, which however records the largest relative year-on-year increase of 190.1 %. Finland itself ranks second in relative growth at 67.4 %, making both Nordic countries the most dynamically expanding in this dimension. Germany maintains a comparatively high absolute ratio as well, yet shows near-stagnation in relative terms at 2.4 %. The Netherlands and France record both lower absolute values and moderate relative increases of 26.5 % and 19.1 %, respectively.

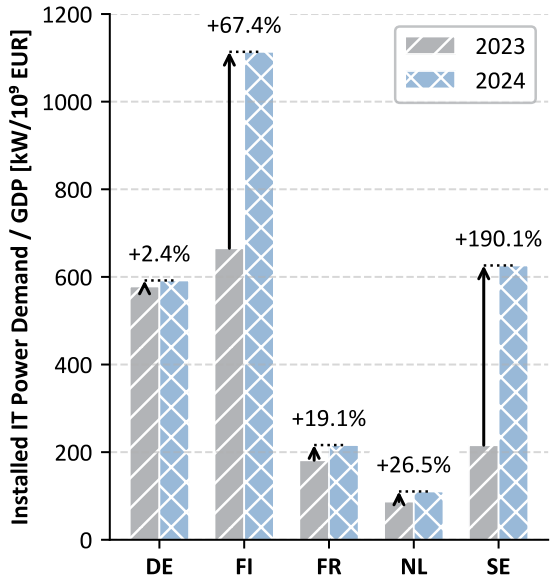


Fig. 7 Ratio of reported installed IT power demand to national Gross Domestic Product (GDP) by country in 2023 and 2024 including the relative annual change, featuring the top five countries by reported installed IT power demand.

The huge growth observed in Sweden and Finland likely reflects continued inflows of investment into Hyperscale data centre in Nordic markets, compounded by the relatively small size of their national economies, which amplifies the metric even for moderate absolute capacity additions [Intelligence, 2025, arizton, 2026, DCByte, 2026, Management, 2025]. In contrast, given Germany's substantially larger GDP, considerable additions to reported IT capacity carry comparatively less weight in the denominator, which may partly explain why the ratio remains stable. The Scandinavian countries, in particular, not only have a high per capita GDP but also a higher per capita electricity consumption for data centres [Azzoni et al., 2026]. This reflects not only the economic strength but also the importance of data centres to the local economy. By 2025, colocation data centres alone are expected to have contributed €53 billion to the European GDP [EUDCA, 2026].

3.4 Data Quality Insights

The estimated reporting coverage are shown in Figure 8, defined as the ratio of EED-registered data centres to the total number of data centres documented in the Data Centre Map from 2026 [DCM, 2026], for each of the five focus countries and for both reporting years (Equation (5)). Overall coverage across the EU was found to be 38 %. All five countries record a notable increase in estimated coverage between 2023 and 2024. Sweden shows the highest relative gain of 66.8 %, but records the lowest absolute coverage ratio in both reporting years, suggesting that despite significant progress, a substantial share of its data centre population is non compliant to EED requierements. Germany, by contrast, shows the smallest relative increase at 17.8 %, but maintains by far the highest absolute coverage ratio in both years, indicating a comparatively mature and comprehensive reporting base. The remaining countries occupy intermediate positions on both dimensions.

This overall pattern reflects a maturation of the EED reporting framework, as regulatory compliance and data collection processes consolidate following the initial rollout. However, improving coverage simultaneously introduces a confounding factor for all year-on-year KPI comparisons presented in Sections 3.2 and 3.3. As the reporting population expands between cycles, its composition changes accordingly. In particular, an increase in the number of smaller or less efficiency-optimised facilities entering the registry will tend to exert downward pressure on aggregate efficiency metrics, irrespective of any genuine performance changes at the level of individual data centres. This effect may partly account for the inter-annual KPI movements observed in the preceding sections, and should be considered when attributing changes in weighted averages to operational developments.

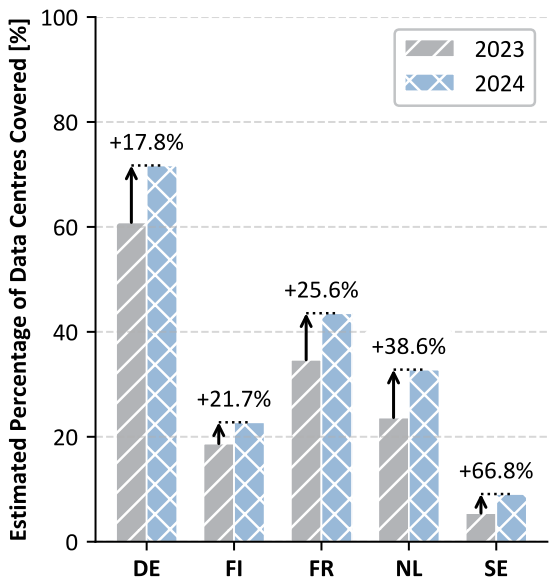


Fig. 8 Estimated reporting coverage of data centres in the EED reporting by country in 2023 and 2024 including the relative annual change, featuring a comparative analysis against the "Datacenter Map" from 2026 [DCM, 2026] for the top five countries by reported installed IT power demand.

DCM's data is based on information provided by operators, external sources, manual data collection, and end users tips [DCM, 2026]. In particular, colocation and cloud services, as well as hyperscalers, are included in the overview. By contrast, enterprise, government and research and development data centres are less represented. To be included in this list, there must be at least 10 racks installed. Despite their best efforts, the information may contain outdated or incorrect data. DCM can also covering installations out of scope of the EED reporting. As part of an EU project, a consortium comprising EY, Borderstep and the AIT has produced an estimate for the registration of data centres [European Commission et al., 2025]. As the data was provided on a voluntary basis, they do not consider the DCM alone to be sufficient for evaluation. Across the European Union, the study estimates coverage at 36 %, with Germany at 73 % and France at 50 % showing a similar level of coverage.

In early 2024, the authors were provided with aggregated extracts from the German register for the year 2023 by the responsible German authority. Due to a definition of power ranges that differs from that of the EU, a comparative analysis can only be meaningful for very small data centres. Here, the German data showed a number of 76, whilst the German EU data reported 55 (−27.6 %) data centres for 2023 and 71 (−6.6 %) for 2024. In terms of total numbers, the internal data show a total of 344 across all power ranges, whereas 314 (−8.7 %) data centres were reported in 2023 and 370 (+7.6 %) in 2024. The main reason for these differences, particularly in the low-power range, is the varying design of the legislation [European Union, 2023, ene, 2023]. Whilst EU reporting requirements apply from at least 500 kW installed IT demand, the threshold in Germany is currently 300 kW of grid connection capacity. In a recent response from the German Federal Government, it was stated that 460 data centres had reported their data to the relevant authorities for 2024, of which 116 had an IT power of less than 500 kW [Bundesregierung, 2026]. It is likely that data centres, which are not subject to mandatory reporting, were not taken into account when the data was submitted to the EU. However, the reports are roughly in the same overall range. At the same time, as a result of the EnEfG, fine proceedings based on non compliance to reporting obligations were initiated against six operators with a total of 39 data centres [Bundesregierung, 2026].

4 Discussion

The empirical findings extracted from the initial releases of the EU Energy Efficiency Directive (EED) Data Centre Dashboard provide an unprecedented baseline, yet they simultaneously expose substantial discrepancies when cross-referenced with established industry studies and market projections. While the Joint Research Centre (JRC) of the EU previously estimated that the total electricity consumption of data centres within the EU would range between 45 TW h to 65 TW h by 2022 [European Commission. Joint Research Centre., 2024], our analysis of the registry shows an aggregated energy consumption of just 11.2 TW h in 2023 and 16.8 TW h in 2024. This glaring deficit indicates that the current EED database captures only a fraction of Europe's

true digital infrastructure footprint. This is further validated by our estimated overall coverage ratio of approximately 38 % when benchmarking registrations against the Data Center Map [DCM, 2026]. Market evaluations compiled by the European Data Centre Association (EUDCA) support this narrative, revealing that historical operational capacities in leading markets like Germany, France, and the Netherlands had already reached cumulative energy demands significantly higher than what is reflected in the official registry [EUDCA, 2024].

A core reason for these discrepancies lies in the structural maturity of national reporting workflows and legislative thresholds. As noted in Section 3.4, Germany's high reporting coverage (71.7 %) stems from its proactive national implementation via the Energy Efficiency Act (*EnEfG*), which enforces a stricter reporting threshold of 300 kW compared to the EU's 500 kW baseline [ene, 2023, European Union, 2023]. Conversely, the exceptionally low coverage observed in Sweden (9.1 %) and Finland (22.8 %) underscores significant regulatory lag or non-compliance during these initial reporting cycles.

Our dynamic year-on-year analysis demonstrates that macro-level performance metrics are highly sensitive to these data-capture irregularities. The 2.9 % deterioration of the calculated average PUE in the Netherlands, alongside the massive 63.0 % volatility in its WUE, can be mathematically traced to compositional bias, specifically, an influx of smaller and less efficient enterprise data centres registering between 2023 and 2024 rather than a genuine physical decline in operational efficiency. This structural instability presents a fundamental challenge for policymakers: as long as registry participation expands unevenly, country-level weighted averages will remain skewed by the shifting typology of reporting facilities rather than reflecting actual technological trajectories.

Furthermore, the multidimensional evaluation highlights critical ecological trade-offs. The inverse relationship between PUE and WUE observed in the Dutch and German cohorts emphasizes that minimizing electrical overheads often occurs at the expense of intensified water consumption through evaporative cooling methodologies [Patterson et al., 2011]. Lastly, the Energy Reuse Factor (ERF) metrics remain persistently close to zero across almost all major markets. Even in Nordic countries like Finland and Sweden, which benefit from extensive municipal district heating grids, widespread waste heat integration remains a localized exception rather than a sector-wide standard [Ott and Radgen, 2024]. This indicates that mandatory minimum energy efficiency standards must be supplemented by cross-sectoral infrastructure planning to bridge the gap between data centre thermal outputs and local heat demands.

5 Conclusion

This paper provided a comprehensive analysis and systematic refinement of the first official EU Data Centre Registry dataset under the recast Energy Efficiency Directive (EED). By establishing an automated data-processing pipeline, we successfully harmonized the initial dashboard releases, calculated crucial performance metrics, and identified systemic data quality anomalies. Our findings confirm a highly uneven European data centre landscape, characterized by a sharp geographic efficiency gradient that favors northern member states due to climatic advantages, specialized infrastructure design, and access to renewable energy capacities.

However, the primary insight of this evaluation centers on the current limitations of the EED reporting framework itself. With an estimated overall EU data centre coverage rate of only 38 % and extreme inter-annual metric volatility caused by compositional shifts in reporting populations, the current dataset must be utilized with exceptional caution. Structural data gaps, late-stage operator reporting corrections, and impossible statistical outliers, such as utilization rates exceeding 100 % in Denmark and Malta, indicate that data auditing workflows require substantial improvements.

For the EED registry to fulfill its intended role as the empirical foundation for a future mandatory net-zero transition timeline, the European Commission must harmonize reporting completeness and robustness of data quality, introduce standardized automated validation constraints, and account for compositional facility adjustments in year-over-year reporting. Future research should leverage our refined dataset to track long-term efficiency trajectories as compliance rates

mature, ensuring that policy targets are guided by accurate, resilient data.

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Appendix A Additional Data

Table A1 Comprehensive country-level comparison of data centre metrics in 2024, compiling primary EED and external source data alongside secondary calculated socio-economic and performance ratios (indented).

Parameter	**Unit**	**DE**	**FI**	**FR**	**NL**	**SE**
PUE[1]	-	1.35	1.14	1.44	1.41	1.14
PUE[2]	-	1.38	1.16	1.49	1.44	1.14
WUE[2]	L/kWh	0.486	0.009	0.263	0.877	0.044
ERF[2]	-	0.009	0.074	0.004	0.025	0.000
REF[2]	-	0.93	0.99	0.80	0.64	0.98
Reported Data Centres (EED) [European Commission, 2026a]	-	370	28	152	61	10
Reported Data Centres (DCM) [DCM, 2026]	-	516	123	349	186	110
Coverage of Reported Data Centres	%	71.7	22.8	43.6	32.8	9.1
Total Energy Consumption of Data Centres	TWh	5.26	1.38	3.17	0.88	1.14
Installed IT Power Demand	GW	2.56	0.31	0.63	0.12	0.35
Total Energy Consumption of IT Equipment	TWh	3.90	1.21	2.20	0.62	1.00
Full Load Operating Hours	h	1521	3925	3587	5025	2863
Utilization of IT Equipment	%	17.3	44.7	39.7	57.2	32.6
GDP	10^9 EUR	4,329	276	2,919	1,121	559
GDP / Installed IT Power Demand	10^6 EUR / kW	1.69	0.90	4.63	9.07	1.60
Installed IT Power Demand / GDP	kW/10^9 EUR	591.9	1,113.7	216.2	110.3	626.1
Energy Consumption of IT / GDP	MWh/10^9 EUR	900.1	4,370.9	753.8	554.0	1,792.8
Energy Consumption of Data Centres / GDP	MWh/10^9 EUR	1,215.8	4,986.2	1,084.0	781.3	2,042.2
Electricity Consumption per Country	TWh	475.4	76.7	410.7	109.6	124.7
Share of IT Energy Consumption	%	0.82	1.57	0.54	0.57	0.80
Share of Data Centre Energy Consumption	%	1.11	1.79	0.77	0.80	0.92
Population	10^6	83.50	5.60	68.67	17.94	10.55
Capita / Installed IT Power Demand	1/kW	32.57	18.23	108.78	145.09	30.14
Installed IT Power Demand / Capita	W	30.70	54.85	9.19	6.89	33.17
Energy Consumption of IT / Capita	kWh	46.69	215.27	32.05	34.63	94.99
Energy Consumption of Data Centres / Capita	kWh	63.07	245.57	46.09	48.84	108.21
Cooling Degree Days	d	19	0	61	7	0

[1]Calculated average, calculated with Equation (1).

[2]Weighted average, using the total energy consumption as the weighting factor. [European Union, 2024]

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