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Development of an energy efficiency label for data centres

Contribution to the discussion for more transparency in the digital economy

Jens Gröger, Felix Behrens, Oeko-Institut e.V.

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1 Introduction

Energy efficiency is playing an increasing role in the selection of products and services. In the consumer surveys on environmental awareness that are continuously conducted by the German Federal Environment Agency, more than three quarters of all consumers state that they prefer "appliances with a particularly good energy efficiency class" when asked about their personal behaviour to protect the environment (Umweltbundesamt 2021). What is now taken for granted when buying household appliances is also an important selection criterion for cars with the obligatory information on fuel consumption per 100 kilometres or for buildings with the energy certificate, which shows the primary energy demand per square metre.

For data centres and IT services, however, such a clearly visible indication of efficiency is still missing. Even if private or professional customers are willing to spend more money on more environmentally friendly products, this wish has so far failed due to the lack of transparency in the data centre industry.

Against this background, the PeerDC project ("Public Energy Efficiency Register of Data Centres", https://peer-dc.de/) on behalf of the Federal Environment Agency has set itself the sub-goal of developing an energy efficiency label for data centres. The labelling is based on key performance indicators (KPIs) that are recorded within a voluntary data centre register that is also being developed in this project. As far as possible, these KPIs are defined in the DIN EN 50600 series of standards. In addition, further IT-specific indicators are proposed if there are no international standards yet. The input parameters for the labelling scheme were selected in such a way that they are comparatively easy to collect and do not require a high level of additional measurement effort on the part of the data centre operators.

The energy efficiency label for data centres that is developed here, is meant as a contribution to the discussion for more transparency in the digital economy. This label must be verified and further developed through further practical experience.

2 Approach

When operating a data centre, two technical areas must be distinguished:

- the operation of the building technology (cooling systems, power supply, security technology)
- and the operation of information technology (servers, storage systems, network technology).

Often there are even economically separate companies, or at least different departments within a company, that are responsible for these two areas. For example, the operator of a co-location data centre provides a secure physical environment through the use of building technology, on which a customer then sets up his own information technology. In a corporate data centre, one department is responsible for the fail-safe operation of the building technology, while the other department sets up the IT components and is responsible for their IT security. The efficiency of the entire data centre depends on everyone achieving a high level of efficiency within their area of responsibility. Therefore, sustainability indicators are needed for both areas, which provide information on how efficient the current operation is and which changes contribute to optimisation. For a data centre indicator to be developed, both areas must therefore first be addressed separately before they are presented together in one label for the entire data centre.

In the PeerDC research project, a data centre register is being set up in which the operators of data centres and information technology enter all the essential information that is relevant for an evaluation of energy efficiency, e.g. information on energy consumption and efficiency parameters. In such a register, the data centres can make their sustainability efforts publicly visible and thus enter into a competition for the most sustainable data centre service.

The following key figures, which describe the **efficiency of the building technology**, are recorded in the voluntary register:

- PUE - Power Usage Effectiveness (DIN EN 50600-4-2) measures the efficiency of building technology as the ratio of the energy consumption of the entire data centre and the energy consumption of the IT within one year.
- CER - Cooling Efficiency Ratio (DIN EN 50600-4-7) measures the efficiency of the cooling system as the ratio of the produced cooling energy and the energy used for the appliances in a year.
- ERF - Energy Reuse Factor (DIN EN 50600-4-6) measures the ratio of the discharged energy that is put to a sensible subsequent use, e.g. in the form of waste heat utilisation.
- WUE - Water Usage Effectiveness (DIN EN 50600-4-9) measures the efficiency of water use as a ratio of the amount of water consumption and the energy consumption of the IT within a year.
- REF - Renewable Energy Factor (DIN EN 50600-4-3) measures the share of renewable energy in the total energy consumption of the data centre. It does not describe the efficiency of electricity generation, but its consistency (generation).

As a key figure for the **efficiency of information technology,** the PeerDC register initially considers only the average CPU utilisation of the servers to be a suitable indicator that has already been standardised:

- $ITEU_{SV}$ - Information Technology Equipment Utilisation for Servers (ISO/IEC 30134-5) measures the average utilisation of all active servers in a data centre over one year.

Other key performance indicators that describe the efficiency of the information technology of a complete data centre have so far only been used very rarely in practice and, moreover, are not standardised. In the research project of the German Federal Agency for Environment KPI4DCE ("Key Performance Indicators for Data Centre Efficiency"), the research group (Schödwell et al. 2018) developed a metric to relate the performance of a data centre (benefits: computing operations, storage space, network traffic) to the environmental expenditure required for it (energy demand, greenhouse gas emissions, raw material demand, water consumption). These 3 benefits and 4 expenses result in a total of 12 different efficiency indicators. However, the application of the KPI4DCE methodology requires a comparatively high measurement and evaluation effort, which is why the method cannot be used as a basis for data centre labelling at this time. An overview of other internationally developed metrics can be found in the study "Energy Efficiency Metrics for Data Centres" (Maagøe 2022).

Measuring the efficiency of individual IT components is more widespread than metrics that target the efficiency of whole data centres. Here there are suitable performance metrics, such as the SPECPower Benchmark[1] and the SPEC Server Efficiency Rating Tool (SERT) (Kistowski et al. 2021). The SPEC SERT value is used for servers sold in Europe. It is mandatory by the Ecodesign Regulation for Servers and Data Storage Products (Verordnung (EU) 424/2019). For storage systems, the same Ecodesign Regulation also sets a mandatory efficiency score, the SNIA Emerald[2] developed by the Storage Networking Industry Association (SNIA).

[1] https://www.spec.org/power_ssj2008/
[2] https://www.snia.org/tech_activities/standards/curr_standards/emerald

What these performance indicators have in common is that they can be applied to individual server and storage products. The measurements are usually carried out by the manufacturers of the IT components or by specialised test laboratories, in the form of a test run of the respective benchmark software on the test bench. The results of these tests describe the respective hardware configuration and can be published in the product data sheets as constant values.

What these benchmarks are not able to deliver is to describe the efficiency of IT equipment in real-world operation, i.e. in actual use in the data centre under changing conditions such as fluctuating workloads. Furthermore, they only refer to individual devices and not to the servers, storage systems and network components operating together in a data centre. Additionally, the performance benchmarks cannot be collected live, i.e. parallel to the productive operation of the data centre.

For an energy efficiency label for data centers, in contrast to the performance benchmarks described above, such efficiency metrics are looked for that can be measured without great effort - even in live operation. Which can be optimized by operational management. And which are basically suitable for comparing different data centers and IT architectures with each other.

The indicator $ITEU_{SV}$ described above, which initially only gives information about the average utilisation of the servers of a data centre, can in principle be further developed into such an efficiency indicator. Similarly, the utilisation of storage systems and network components can be developed into efficiency indicators.

The following two chapters show, separately for the two areas of Building technology and Information technology which indicators are suitable for describing energy efficiency and how these can be translated into an overarching energy efficiency index. In the final chapter, these considerations are then translated into a common Energy efficiency label for data centres which, comparably to the energy efficiency labelling for products or the energy performance certificate for buildings, can be quickly understood and classified by potential customers.

3 Building Technology

The building technology of a data centre ensures in particular that the IT is cooled permanently, that short-term power failures are bridged by a battery-powered uninterruptible power supply and that the information technology is also supplied with an emergency power supply (usually operated by diesel) in the event of longer power failures.

Most of the energy consumption of the building technology can be attributed to the mechanical work in the cooling system and in the energy losses power supply. In addition, the building technology can ensure a useful reuse of waste heat. The following three efficiency indicators are therefore selected as input parameters to describe the energy efficiency of the building technology od data centres:

- PUE - Power Usage Effectiveness
- CER - Cooling Efficiency Ratio
- ERF - Energy Reuse Factor

The key figures WUE - Water Usage Effectiveness and REF - Renewable Energy Factor described above, on the other hand, were not taken into account for the energy efficiency labelling. The evaluation of WUE depends strongly on the geographical location of the data centre, namely whether there is a local water shortage or not. Water is used in data centres primarily in evaporative cooling, thereby reducing energy use. Whether it is environmentally sound to accept a higher water requirement for data centre air conditioning therefore depends on the individual case. Consideration should be given to showing water consumption separately as an absolute value instead of in an efficiency indicator, or to combining it with a water scarcity indicator. The REF describes the share of renewable energy in the energy consumption of the data centre. This is also not an indicator of energy efficiency, but rather a location factor or a question of contract design with the energy supplier. Both values WUE and REF are therefore well placed in a data centre register, but not in an energy efficiency indicator.

The following describes how the key figures PUE, CER and ERF are translated into a uniform scoring system with a range of values between 0 and 100 points so that they can be aggregated into a common energy efficiency index (EEI) for building technology.

3.1 PUE - Power Usage Effectiveness

The Power Usage Effectiveness (PUE) is defined according to DIN EN 50600-4-2 as:

$$PUE = \frac{E_{DC}}{E_{IT}} \quad (1)$$

With:

- E_{DC} the total energy consumption of the data centre (annually) in kWh,
- E_{IT} the energy consumption of the IT equipment (annually) in kWh.

The theoretical value range of the PUE is [1;∞]. Typical PUE values, according to a survey by GDA and pwc (2020) which was carried out among "well-known data centre operators", between 1.05 and 2.20 with a mean value of 1.38. In the survey regularly carried out by the Uptime Institute among more than 500 international data centre operators (Uptime Institute 2021) the average value for the PUE in 2021 is 1.57, while in 2007 it was still 2.5. For an energy efficiency index, the two extreme values 1.1 for the best available technology and 2.5 for the most inefficient data centre are chosen.

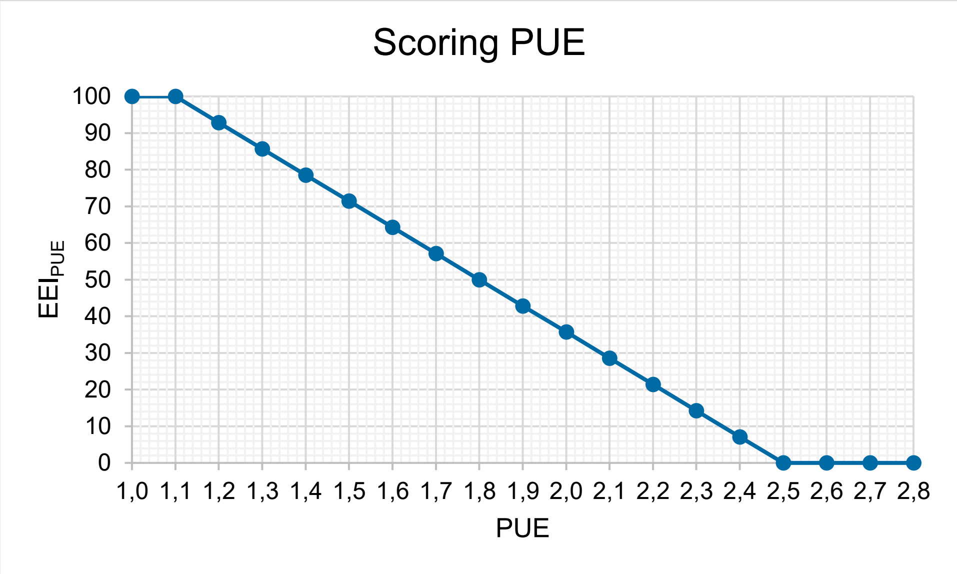
These typical PUE values are converted into an energy efficiency index (EEI) between 0 points (worst value) and 100 points (best value) using the formula described below:

$$EEI_{PUE} = \frac{500}{7} \cdot (2.5 - PUE) \quad (2)$$

- PUE > 2.5 is set to 0 points, PUE < 1.1 is set to 100 points.

The relationship between PUE and the corresponding EEI score is shown graphically in Figure 1.

Figure 1: Energy Efficiency Index EEI_{PUE}



Source: Oeko-Institut e.V.

3.2 CER - Cooling Efficiency Ratio

The Cooling Efficiency Ratio (CER) is defined according to DIN EN 50600-4-7 as:

$$CER = \frac{Q_{\text{dissipated}}}{E_{cooling}} \quad (3)$$

With:

- $Q_{dissipated}$ as the total (annual) amount of heat dissipated from the data centre in kWh,
- $E_{cooling}$ as the (annual) energy consumption of the cooling systems in kWh.

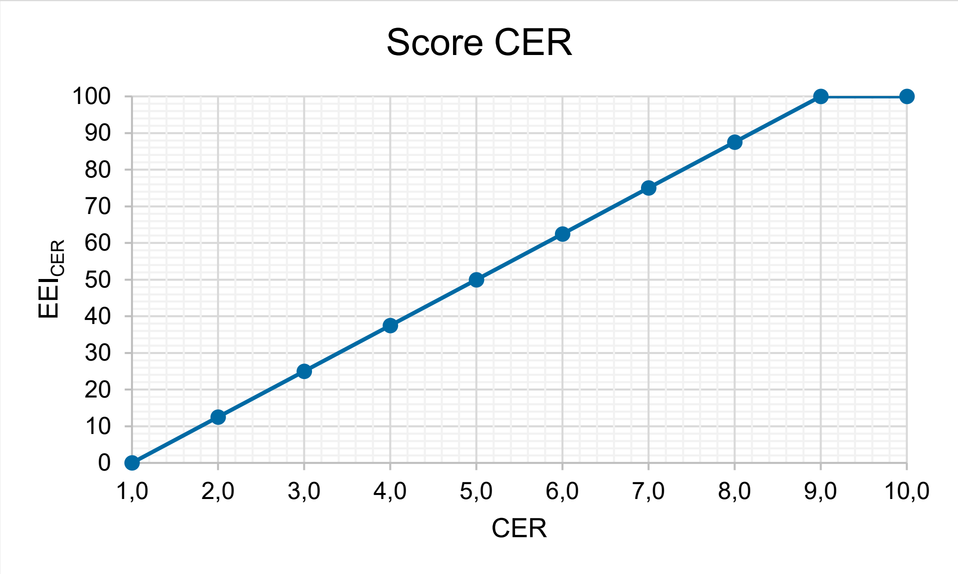
The theoretical value range of the CER is [1;∞]. The eco-label Blauer Engel DE-UZ 228 (2023) which describes the best available technology, requires a value of CER > 9 for new data centres commissioned from 2024 onwards. The value range of the CER is therefore mapped linearly from [1;9] to [0;100] for the energy efficiency index:

$$EEI_{CER} = 12.5 \cdot (CER - 1) \quad (4)$$

- CER ≤ 1 is set to 0 points, CER > 9 is set to 100 points.

The relationship between CER and the corresponding EEI score is shown in Figure 2 graphically.

Figure 2: Energy Efficiency Index EEI_{CER}



Source: Oeko-Institut e.V.

3.3 ERF - Energy Reuse Factor

The Energy Reuse Factor (ERF) is defined according to DIN EN 50600-4-6 as:

$$ERF = \frac{E_{Reuse}}{E_{DC}} \tag{5}$$

With:

- E_{Reuse} as (annual) energy from the data centre in kWh that is used outside the data centre and completely or partially replaces energy there,
- E_{DC} as the (annual) total energy consumption of the data centre in kWh.

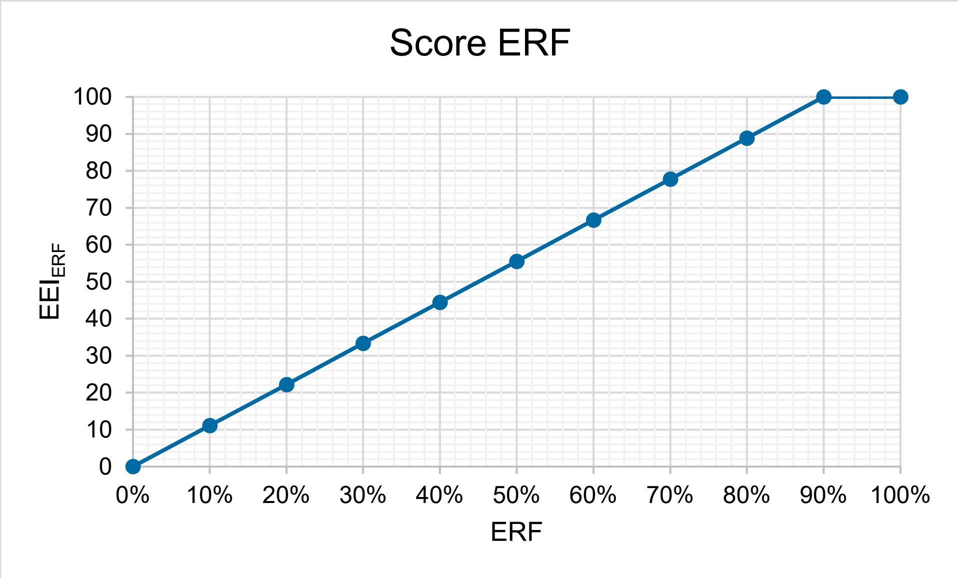
The theoretical value range of the ERF is between 0 and 100% [0;1]. Which of these values occur in practice has not yet been systematically recorded. At least for the location of Germany, it can currently be assumed that most data centres release their waste heat unused into the environment, i.e. have a CER = 0. A study by the German Corporate Initiative on Energy Efficiency (Mira Weber and Benjamin Ott 2023) shows the potential for waste heat utilisation based on a total of 99 practical examples. It can therefore be assumed that high CER ratios are achievable in practice. For physical reasons, 100% reuse is not possible, because there are losses with every heat transfer. Therefore, the maximum is set at CER = 90%. The CER is converted as follows for the energy efficiency index from 0 to 100 points:

$$EEI_{ERF} = ERF \cdot \frac{1000}{9} \tag{6}$$

- ERF > 0.9 is set to 100 points.

The relationship between CER and the corresponding EEI score is shown in Figure 3 graphically.

Figure 3: Energy Efficiency Index EEI_{ERF}



Source: Oeko-Institut e.V.

3.4 Energy Efficiency Index for Building Technology

The three individual energy efficiency indices EEI_{PUE}, EEI_{CER} and EEI_{ERF} are now to be combined into a single indicator, an energy efficiency index for building technology EEI_{BT}, where BT stands for *Building Technology.*

Since PUE and CER are not independent of each other, it would be wrong to simply average all three values. CER affects PUE, but not the other way around, which is why the former should come in with a lower weighting factor so as not to count it twice. The reuse of energy ERF is an important issue for reasons of decarbonisation of the heat supply, but it is not entirely in the hands of the data centre operator. This is because there must also be corresponding heat consumers in the neighbourhood of the data centre for sensible subsequent use.

We therefore propose the following weighting factors:

- EEI_{PUE} : 40%,
- EEI_{CER} : 20%,
- EEI_{ERF} : 40%.

This results in the efficiency index for the data center's building technology:

$$EEI_{BT} = 0.4 \cdot EEI_{PUE} + 0.2 \cdot EEI_{CER} + 0.4 \cdot EEI_{ERF} \quad (7)$$

With:

- EEI_{BT} as an energy efficiency index for building technology with values from 0 to 100 points.

Or after inserting the formulas (2), (4) and (6):

$$EEI_{BT} = \frac{200}{7} \cdot (2.5 - PUE) + \frac{5}{2} \cdot (CER - 1) + \frac{400}{9} \cdot ERF \quad (8)$$

4 Information Technology

The information technology (IT) of a data centre represents the actual benefit of the data centre. This is because the building technology is only operated to ensure that the right environmental conditions are provided for the information technology. In addition to the energy efficiency index for building technology, suitable key figures are therefore also needed for IT.

When developing an energy efficiency index for information technology, we made sure to use existing data wherever possible, or at least data that can be collected without much effort. In the case of IT, this is usually either static data that can be read from the technical data sheets or measured data on current operating states that are monitored by existing monitoring tools anyway, if only to ensure fail-safe operation.

The starting point for the development of an energy efficiency indicator is therefore the measured utilisation, such as the CPU utilisation for servers, the utilisation of storage systems and the utilisation of network components combined with other easily collectable data. In practice, there is a direct correlation between the utilisation and energy efficiency of IT components. This is because IT requires energy even when it is not being used, the so-called idle losses. The higher the utilisation of IT, the lower the impact of these idle losses.

In the following chapters, the correlation between load and energy consumption of servers is first examined in order to then develop a corresponding energy efficiency indicator for all three relevant components of information technology, servers, storage systems and network devices.

4.1 Relationship between utilisation and efficiency

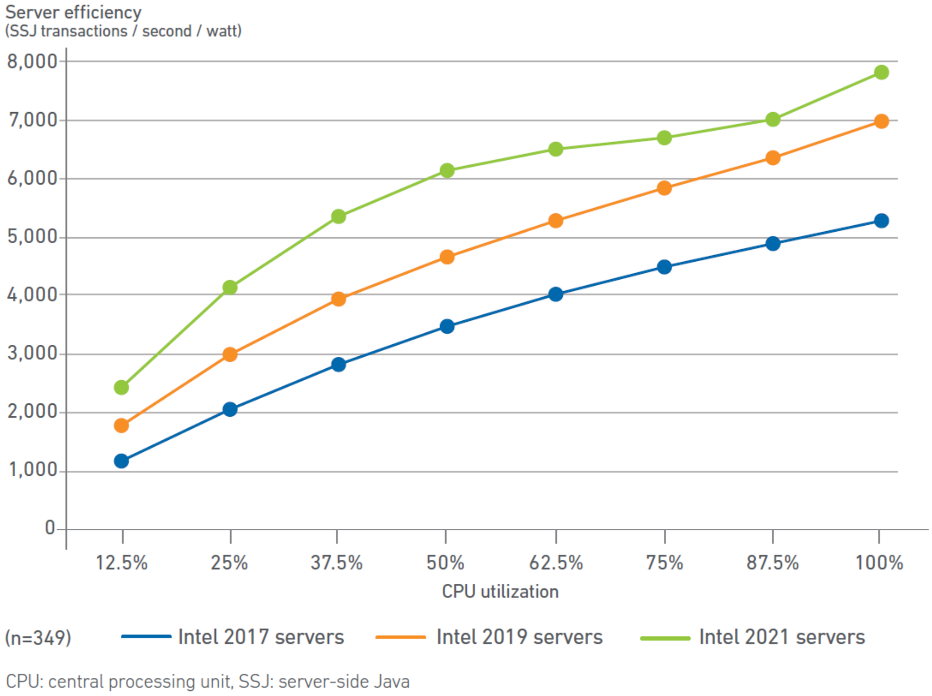
With efficiency metrics for servers, such as the SPECPower Benchmark (SPECpower Committee 2014) which measures the executable computing operations per electrical power used, it can be shown very clearly that there is a direct correlation between CPU utilisation and energy efficiency. This is also logical in that a high proportion of the energy consumption, often up to 50%, is accounted for by the idle mode, which does not perform any useful work.

Efficiency increases with each server generation due to technical progress. However, the correlation between utilisation and efficiency remains. This is also shown by a current evaluation of the Green Grid database with 429 server platforms (The Green Grid's Server Efficiency Rating Tool (SERT) database) by the Uptime Institute (Tomas Rahkonen and Jay Dietrich 2023). Figure 4 below shows these results. The lowest server efficiencies, measured as computing operations per second and watt, are achieved at the lowest measured utilisation of 12.5%, the highest at 100%.

Efficiency increases with each server generation due to technical progress. However, the correlation between utilisation and efficiency remains. This is also shown by a recent evaluation of the Green Grid's Server Efficiency Rating Tool (SERT) database of 429 server platforms by the Uptime Institute. (Tomas Rahkonen and Jay Dietrich 2023). In the following Figure 4 shows these results. The lowest server efficiencies, measured as computing operations per second and watt, are achieved at the lowest measured utilisation of 12.5%, the highest at 100%.

This figure also shows that older servers from 2017 can very well achieve the same efficiencies as servers from 2021 if they are themselves more heavily utilised. Replacing an old server with a significantly more powerful and efficient server only leads to energy savings if the new server is actually working with a high CPU-utilization and not in the lower partial load range.

Figure 4: Server efficiency depending on CPU utilisation and server generation



Source: Figure taken directly from Uptime Institute (Tomas Rahkonen and Jay Dietrich 2023)

In order to capture the issue of underutilised servers and server farms with a metric, Harryvan (2021) developed the *Server Idle Coefficient (SIC)* metrics for individual servers and the *Data Centre Idle Coefficient (DCIC)* for entire data centres. The SIC is calculated by the ratio of the energy consumption for idle mode (E_{Idle}) to the energy consumption of the server (E_{Server}):

$$SIC = \frac{E_{Idle}}{E_{Server}} \tag{9}$$

The DCIC is calculated the same way for the total idle losses and server energy consumption of the entire data centre.

If the power consumption in idle mode (P_{idle}) and the power consumption in operating mode (P) are inserted into the formula for the energy consumption, it becomes clear that there is also a direct correlation between the SIC value and the CPU utilisation:

$$SIC = \frac{P_{idle} \cdot \sum_{n=1}^{N} \left(1 - CPU(n)\right) \cdot t(n)}{\sum_{n=1}^{N} P(n) \cdot t(n)} \tag{10}$$

The following applies:

- n is the number of the measuring interval,
- CPU(n) is the CPU load measured at time n,
- P_{idle} is the electrical power consumption in the idle state,
- P(n) is the power consumption of the server measured at time n,
- t(n) is the length of the measurement interval,
- N is the number of measurements.

With the SIC value, it is therefore possible to combine the two variables of CPU utilisation and idle power consumption and represent them in a common indicator. Strictly speaking, this indicator is not an efficiency indicator, but an ineffectiveness indicator, since the minimum value represents the optimum (no losses, lowest ineffectiveness) and the maximum value represents the worst case (exclusively idle losses, 100% ineffective).

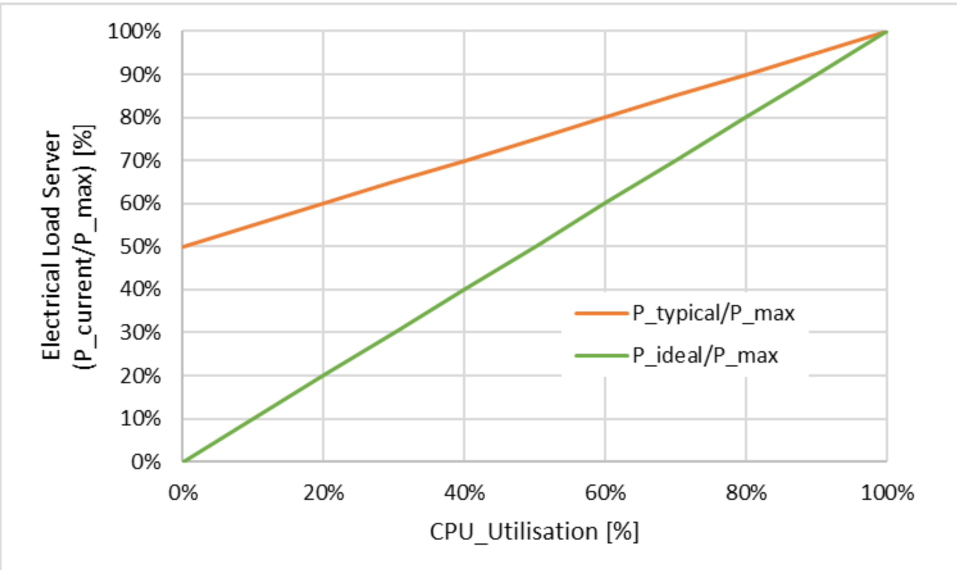
Based on the reflections of Harryvan (2021), efficiency ratios for servers, storage systems and network devices are developed below that turn the principle around in terms of an efficiency ratio and describe how much utilisation is achieved by the IT devices and how this correlates with the share of energy consumption. The ratios are called *load correlations* because they express how well the devices succeed in matching the actual utilisation (useful work) with the energy consumption (effort). The optimum is reached when the load and the share of maximum energy consumption just match.

4.2 Server

For servers, as shown above, the aim is to achieve the highest possible utilisation in order to enable high efficiency. In addition, it is desirable that idle losses are as low as possible and that the servers only consume as much energy as they currently provide CPU load.

In the following Figure 5 below shows the relationship between CPU utilisation and electrical power consumption of servers for a typical server and an ideal server.

Figure 5: Relationship between CPU utilisation and electrical power consumption of typical and ideal servers



Source: Oeko-Institut e.V.

In practice, a server requires energy even when it is in idle mode, i.e. when its CPU load is at 0%. With typical servers, these idle losses account for up to 50% of the maximum power consumption (P_{Server_max}). If this server is 50% utilised, it requires 75% of the maximum power consumption. If the same server is fully utilised (CPU utilisation 100%), its power consumption is 100% of the maximum power consumption (full load mode) and all the energy required can be allocated to the useful work of the server. This relationship of a typical server is shown above by the orange line. The only way to run such a server optimally is to load it as high as possible (close to 100%). An ideal server, shown above with the green line, on the other hand, has no idle losses and reduces its power consumption just about to the same extent as the CPU utilisation claimed. A CPU load of 0% thus leads to a power consumption of 0, a CPU load of 50% to a power consumption of 50% of the maximum power consumption, and in the case of full utilisation, CPU load and power consumption are equally at 100%. For an ideal server, it is therefore irrelevant from the point of view of energy efficiency how heavily it is utilised.

The key figure developed here takes both influencing factors into account: CPU utilisation and the server's ability to reduce its power consumption as CPU utilisation decreases. Instead of the power consumption in idle mode (P_{idle}), which is used in the SIC value, the maximum possible power consumption of the server in full load mode (P_{Server_max}) is used here as a reference value. This value is a fixed electrical power value per server, which, according to the Ecodesign Regulation for Servers and Storage Systems (Verordnung (EU) 424/2019) since 1 March 2020, must be stated in technical data sheets and on the manufacturer's website. Alternatively, this value can also be measured yourself by putting the servers under maximum load (under Linux, for example, with the `stress` command).

The new indicator is called *load correlation (LC)* in the following because it describes how well IT utilisation correlates with energy utilisation. The already established key figure IT Equipment Utilisation of Servers ($ITEU_{SV}$) is used as a value for the annual average CPU utilisation of all servers. It is defined:

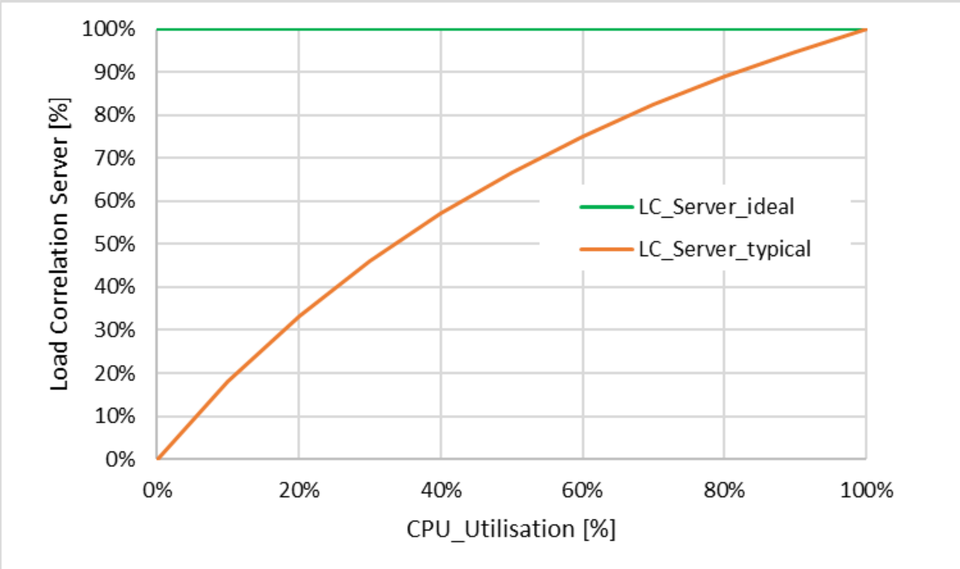
$$LC_{Server} = \frac{ITEU_{SV}}{\left(\frac{E_{Server}}{P_{Server\_max} \cdot t}\right)} \quad (11)$$

With:

- LC_{Server} as dimensionless load correlation of the servers (0 to 100%),
- $ITEU_{SV}$ as average (annual) CPU utilisation of the servers (0 to 100%),
- E_{Server} as (annual) energy consumption of all servers in kWh,
- P_{Server_max} as the sum of the maximum power consumption of all servers in full load mode in kW,
- t as the measurement period in hours, for an annual value this corresponds to 8760h.

If one calculates the load correlation for the Figure 5 above for a typical server (orange) and for an ideal server (green), the curves shown in the following Figure 6 below are obtained depending on the CPU utilisation. The typical server (orange) shows an increasing value for the load correlation, which starts at LC_{Server} = 0% for the CPU utilisation of 0% and reaches its maximum of LC_{Server} = 100% when the CPU utilisation is 100%. The ideal server, on the other hand, has a load correlation of LC_{Server} = 100% over the entire range of values for CPU utilisation, i.e. it works optimally at every utilisation state.

Figure 6: Relationship between CPU utilisation and load correlation (LC_{Server}) of typical and ideal servers



Source: Oeko-Institut e.V.

4.3 Storage systems

The approach to calculating load correlation presented above for servers can be equally applied to storage systems. Here, the useful work of the storage system usually consists of storage space allocation. Analogous to above, it is therefore defined that the load correlation for storage systems ($LC_{Storage}$) is the ratio between percentage storage utilisation and proportional energy consumption of the storage to its maximum energy consumption:

$$LC_{Storage} = \frac{Storage\_Utilisation}{\left(\frac{E_{Storage}}{P_{Storage\_max} \cdot t}\right)} \quad (12)$$

With:

- $LC_{Storage}$ as dimensionless load correlation of the storage systems (0 to 100%),
- Storage_Utilisation as average (annual) storage space utilisation (0 to 100%),
- $E_{Storage}$ as (annual) energy consumption of all storage systems in kWh,
- $P_{Storage\_max}$ as the sum of the maximum power consumption of all fully occupied storage systems in kW,
- t as the measurement period in hours, for an annual value this corresponds to 8760h.

For storage systems, it can be argued that their energy consumption does not correlate with storage space utilisation, but rather with data throughput during read and write activities. Therefore, if the storage space utilisation is taken as the unit of useful work, the energy consumption remains constant. To simplify, both energy consumptions $E_{Storage}$ and ($P_{Storage\_max}$ * t) can be set equal, which leads to a denominator of 1 and allows the following simplification of the calculation rule:

$$LC_{Storage} \approx Storage\_Utilisation \quad (13)$$

The effectiveness of the storage system can therefore be equated with the (annual) percentage storage space utilisation. This is also logical insofar as an unused storage unit only consumes energy unnecessarily, while a fully used storage unit uses the system to the maximum.

4.4 Network devices

Network switches (multiport bridge devices) are the most important components of the network infrastructure in a data centre. They are therefore used here to make a statement about the percentage utilisation of the network infrastructure.

Original considerations to use the transmitted data volumes in relation to the maximum data transmission as the benefit of the network switches were discarded because monitoring data on internally and externally transmitted data volumes are insufficiently collected in data centres and because, in addition, there is no direct correlation to the energy consumption of network switches and their transmitted data volumes.

In contrast to the amount of data transmitted, however, the proportion of connected physical ports correlates with the energy consumption of network components, as unconnected ports can be put into standby mode (cf. "Energy-Efficient Ethernet Standard" IEEE 802.3az).[3]

It applies to the network utilisation:

$$Network\_Utilisation = \frac{Ports_{connected}}{Ports_{available}} \tag{14}$$

Ports here refers to the number of physical ports of all multiport bridge devices. For the load correlation for network devices ($LC_{Network}$), the network load is defined as the ratio of the number of connected ports with the number of available ports, for the share of energy consumption the quotient of measured energy consumption to the maximum energy consumption with full port occupancy:

$$LC_{Network} = \frac{Network\_Utilisation}{\left(\frac{E_{Network}}{P_{Network\_max} \cdot t}\right)} \tag{15}$$

With:

- $LC_{Network}$ as dimensionless load correlation of the network (0 to 100%),
- Network_Utilisation as the average (annual) utilisation of physical ports (0 to 100%),
- $E_{Network}$ as (annual) energy consumption of all network devices in kWh,
- $P_{Network\_max}$ as the sum of the maximum power consumption of all network devices with fully occupied ports in kW,
- t as the measurement period in hours, for an annual value this corresponds to 8760h.

[3] https://standards.ieee.org/ieee/802.3az/4270/

4.5 Energy Efficiency Index for Information Technology

The proposal for calculating an energy efficiency index for information technology is composed of the above three values of the load correlations (LC). A weighted average value is formed, which is weighted according to the share of the total energy consumption of the respective sub-areas of servers, storage systems and network devices in the total energy consumption of information technology. In this way, the energy efficiency index does justice to the situation that in some data centres servers are the largest energy consumers, while in others storage systems or network devices are. It is even possible that only network data centres are evaluated with it, for example data centres from a communication services provider. The approach therefore is therefore applicable to all business models of IT operators:

$$EEI_{IT} = 100 \cdot (LC_{Server} \cdot \frac{E_{Server}}{E_{IT}} + LC_{Storage} \cdot \frac{E_{Storage}}{E_{IT}} + LC_{Network} \cdot \frac{E_{Network}}{E_{IT}}) \quad (16)$$

Whereby the following applies to the energy consumption of information technology (E_{IT}):

$$E_{IT} = E_{Server} + E_{Storage} + E_{Network} \quad (17)$$

The above term becomes by substituting the definitions of the load correlations from (11), (12) and (15):

$$EEI_{IT} = \frac{100}{E_{IT}} \cdot (ITEU_{SV} \cdot P_{Server\_max} \cdot t$$
$$+Storage\_Utilisation \cdot E_{Storage}$$
$$+Network\_Utilisation \cdot P_{Network\_max} \cdot t) \quad (18)$$

With:

- EEI_{IT} as an energy efficiency index for information technology with values from 0 to 100 points,
- $ITEU_{SV}$ as average (annual) CPU utilisation (0 to 100%),
- P_{Server_max} as the sum of the maximum power consumption of all servers in full load mode in kW,
- Storage_Utilisation as average (annual) storage space utilisation (0 to 100%),
- $E_{Storage}$ as (annual) energy consumption of all storage systems in kWh,
- Network_Utilisation as the average (annual) utilisation of physical ports (0 to 100%),
- $P_{Network\_max}$ as the sum of the maximum power consumption of all network devices with fully occupied ports in kW,
- t as the measurement period in hours, for an annual value this corresponds to 8760h.

If the IT operator itself does not operate any network components, for example because it is a customer within a co-location data centre and uses the network components of the data centre operator, the energy consumption of the network $E_{Network}$ can be set to zero for simplification. This is particularly acceptable if it can be assumed that the network components only account for a negligible share of the total power consumption.

5 Energy efficiency label for data centres

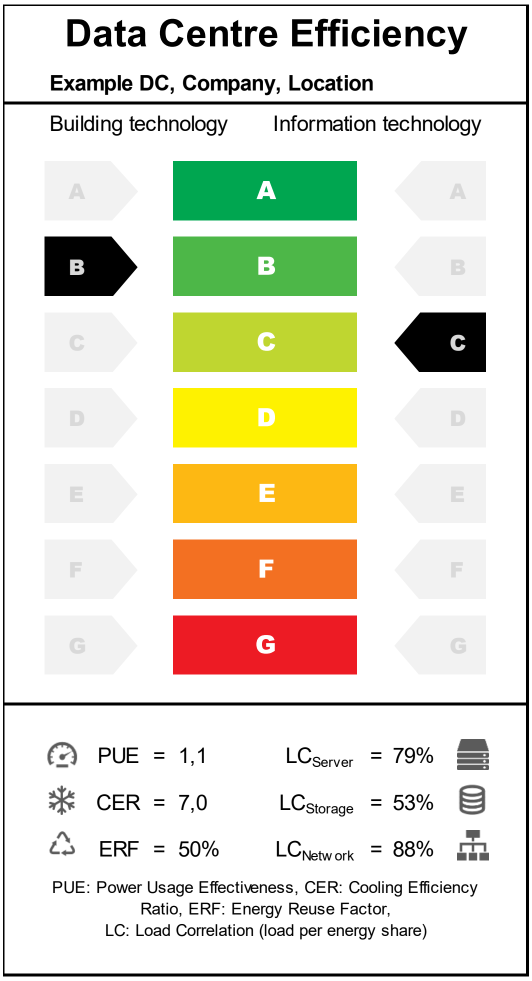
In the last step, the two energy efficiency indices for building technology (EEI_{BT}) and information technology (EEI_{IT}) are each translated into an efficiency class, as we are familiar with from the EU energy efficiency label. The range of values from 0 to 100 points is translated into the alphanumeric scale from "A" to "G". "A" represents the best efficiency class, "G" the worst. The assignment is made as shown in the following Table 1 below:

Table 1: Assignment of the energy efficiency index EEI to the efficiency class

EEI	Efficiency class
≥ 90	A
≥ 75 to < 90	B
≥ 60 to < 75	C
≥ 45 to < 60	D
≥ 30 to < 45	E
≥ 15 to < 30	F
< 15	G

Source: Oeko-Institut e.V.

Figure 7: Energy efficiency label for data centres



Source: Oeko-Institut e.V.

In Figure 7 shows an example of how an energy efficiency label for data centres could be graphically designed.

Within the labelling scheme, the energy efficiency indices for building services (EEI_{BT}) and information technology (EEI_{IT}) are deliberately not offset against each other, but are published separately as an efficiency class A to G and are shown next to each other. On the left side the efficiency class for building technology is shown, on the right side the efficiency class for information technology. This retains the information on how efficiently the respective area of the data centre is operating. Providers of co-location data centres thus have the option of showing only the efficiency of the building technology, while IT operators can add their IT-related efficiency class.

The energy efficiency label also provides space for further information, such as the original values of the PUE, CER or ERF, the values of the load correlations and, if required, values for the share of renewable energy (REF) or the water use figures (WUE or absolute water consumption).

The presented calculation rule and the proposals for its visualisation are intended to contribute to data centres making their energy efficiency visible with uniform benchmarks. This will provide an incentive for a fair competition for the most efficient data centre services.

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