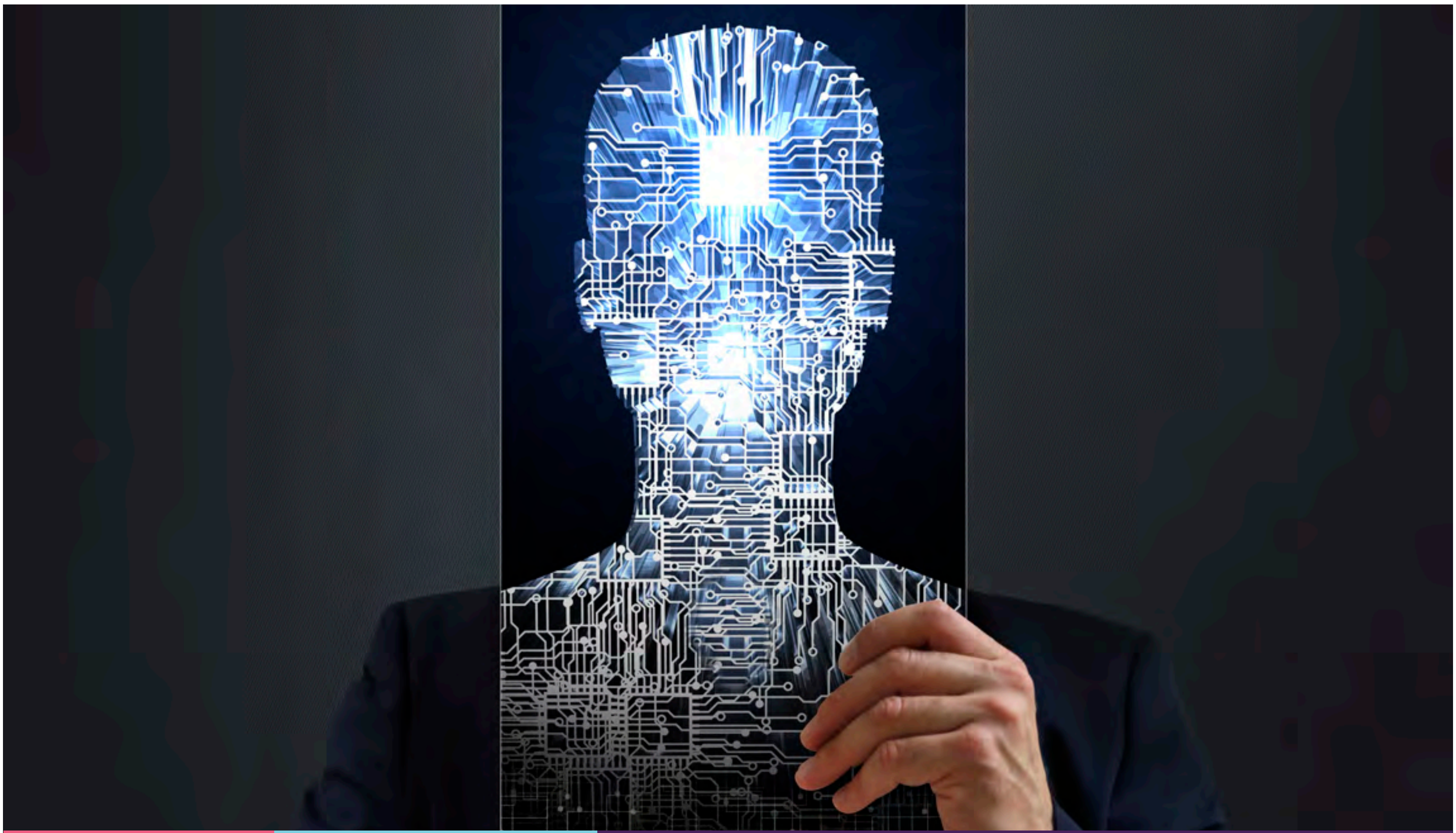

Motiva

Energy Efficiency of Data Centers in Finland

11/2022

Energy Efficiency of Data Centers in Finland – Indicators, Policies and Good Practices

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Energy Efficiency of Data Centers in Finland – Indicators, Policies and Good Practices

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Preface

The objective of this study is to provide an overview of the energy efficiency indicators for the data center industry and factors affecting the energy efficiency of the sector. Energy efficiency of the Finnish data center industry is analysed along with European and national policies and measures in place. Significant new regulation for data collection on the data center industry is presented in the proposed recast of the Energy Efficiency Directive. In addition, some examples of good practices in energy efficiency and waste heat recovery are given.

Particularly compelling data needs arise from the proposed recast of the Energy Efficiency Directive. The planned data collection obligations significantly exceed the data available at the moment and the report reveals the gap.

The use of energy indicators and benchmarking of energy efficiency of countries, sectors and sub-sectors is increasing at the international fora. This necessitates a thorough understanding of underlying factors affecting the comparisons and of the limitations to the interpretations which can be made from the data. Several studies have been made in Finland to better understand them. VTT Technical Research Centre of Finland Ltd carried out a study in 2018 on energy efficiency country comparisons and decomposition analyses as well as ODYSSEE and MURE Scoreboards (Koreneff 2018). In 2019, VTT and Fisher International Inc. carried out another study on how the energy efficiency of the pulp and paper sector in Finland compares to other countries (Koreneff et al. 2019). In 2020, Motiva carried out yet another study in metals production (Gynther and Kiuru, 2020) and in 2021 in the commerce sector (Gynther and Heinaro, 2021).

This project was financed by the Finnish Energy Authority. The Steering Group of the project consisted of the following experts:

- Johanna Kirkinen, the Finnish Energy Authority, Senior Engineer
- Veijo Terho, Chairperson of the Finnish Data Center Association and Verne Global (Ficolo Oy)
- Sami Holopainen, Finnish Data Center Association and Equinix Oy
- Eero Lindqvist, Finnish Data Center Association and Telia Finland Oyj
- Sami Niiranen, Finnish Data Center Association FDCA and consulting company Granlund Oy
- Timo Ranne, Finnish Data Center Association and consulting company Granlund Oy

The study was carried out by Senior Expert Lea Gynther (project manager), Senior Expert Tomi Kiuru and Expert Juhamatti Meetteri at Motiva Oy in 2022.

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1 Introduction

Study Objective

The objective of this study is to provide an overview of the energy efficiency indicators for the data center industry and factors affecting the energy efficiency of the sector. Energy efficiency of the Finnish data center industry is analysed along with policies and measures in place. In addition, some examples of good practices in energy efficiency and waste heat recovery are given.

Study Approach and Report Structure

Data Centers in Finland – Characteristics and Energy Consumption (Chapter 2)
A brief overview of the characteristics of the data center industry and its energy consumption in Finland is given in Chapter 2.

Energy Consumption Trends and Environmental and Energy Efficiency Indicators for Data Centers (Chapter 3)
First, the energy consumption trends of the global data center industry are described. Next, available indicators to measure energy efficiency and sustainability of data centers are presented. Although these Indicators may be technically available, monitoring data is not yet commonplace.

Energy Efficiency Efforts (Chapter 4)
The report includes an overview of international, European and national policies and measures addressing energy efficiency of data centers.

As part of the European policies, the chapter discusses the indicators and data collection requirements in the proposed recast of the Energy Efficiency Directive as well as its other provisions for data centers such as waste heat utilization and energy management requirements.

Companies operating in the sector have actively undertaken measures driven both by business needs to pursue sustainability as well as policy. Some case examples of innovative sustainable solutions are described in the report.

Summary and Conclusions (Chapter 5)
Summary of findings as well as conclusions are given in this chapter.

2 Data Centers in Finland – Characteristics and Energy Consumption

2.1 Industry Structure and Services

A data center is composed of a building and related technical systems, as well as servers and other ICT equipment.

Data traffic within data centers is composed of social networking (22%), search (20%), big data (20%), web (18%), video streaming (10%) and other uses (10%). Big data is the fastest growing segment. From the end-user point of view, data transfer from data centers is composed of video streaming (85% of data traffic), internet and data processing (12%), and gaming and data sharing (3%). (IEA 2021).

Data centers are typically classified in three distinctive groups (COWI 2020):

- Hyperscale data centers (HSDC) are owned by companies operating in the internet. The volume of these data centers has grown rapidly. Their power demand is in the range of 50–300 MW. These data centers are typically among the most energy efficient.
- Co-location/Cloud data centers (CDC) are owned by companies selling data center services. The volume of these services has been growing and is expected to do so also in the future. Power demand is usually under 50 MW.
- Enterprise data centers (EDC) are owned by companies and the public sector. The volume of these data centers has declined and is expected to do so also in the future. Power demand is typically under 2 MW.

2.2 Data Centers in Finland

There is no full listing of different types of data centers available. The Data Center Map website[1] lists 23 colocation data centers in Finland. The Baxtel website[2] lists 13 companies operating 29 data centers in Finland along with some information on the floor area and planned power. The largest ones listed are Google Hamina, Telia Helsinki Pitäjänmäki, Global DC Oy (ex-Yandex) in Mäntsälä, Ficolo The Air, Ficolo Pori The Rock, Hetzner Finland and Equinix Helsinki HE4-7 (four units). Some data on planned power is given on the websites but as it does not seem to be up to date, it is not quoted here. Yet another listing service is Cloudscene[3]. It lists 35 data centers with 52 service providers. Data on all these websites has been sourced on 28 May 2022. On 22 August 2022, DC Byte website[4] shows 17 co-location and 7 self-built data centers in Finland.

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[1] Data Center Map website
[2] Baxtel website
[3] Cloudscene website
[4] DC Byte website, data center database

The Finnish government owns about 30 data centers according to the Government ICT Centre Valtori. The number is expected to decline. Municipalities have mainly outsourced their data center services. (Ministry of Transport and Communications 2020)

Finnish Data Center Association (FDCA[5]) is the industry association representing the data center industry in Finland. It was founded in 2014 and currently has over 90 data center companies as members.

2.3 Energy Consumption Data

2.3.1 National Energy Statistics

Statistics Finland, like statistical authorities in most other European countries, does not prepare statistics of data centers separately from other energy consumption in the ICT sector. In the industrial classification (NACE), hyperscale and cloud data centers are part of the services sector for which comprehensive sub-sectoral energy consumption data is not available in Finland. Energy consumption by data centers owned by enterprises and the public sector is reported as part of the industry, to which these bodies belong in the industrial classifications.

An electricity Datahub – centralised information exchange system for the electricity retail market – started operation in Finland in February 2022. Information related to electricity accounting points, such as customer and consumption data, will be stored in this Datahub. Among other benefits, it will enable Statistics Finland to collect detailed up-to date sub-sectoral data on electricity consumption, including the data center industry. (Fingrid 2022).

2.3.2 Other National Data Sources and Studies

According to a study by ETLA Economic Research (Hiekkanen et al 2020), companies operating in the information sector (Nace 26, 58, 59–60, 61, 62–63)[6] consumed under 1 TWh, i.e., about 1% of total electricity consumption in Finland in 2017. Data centers (Nace 62-63) were estimated to contribute about one quarter.

The Tax Administration collects and publishes information on the electricity consumption of data centers with power demand exceeding 5 MW because since 2014 they have benefited of a shift to the lower electricity tax category out of the two possible. The Tax Administration reports that in 2019 there were five data centers in this category, and they consumed 787 GWh. Since the beginning of 2022, also data centers with power demand 0.5 MW have been moved to the lower electricity tax category, if they are energy efficient (see Chapter 4.5). Hence, information on electricity consumption will be available from an increasing number of data centers.

The environmental permit procedures have only shown the energy consumption data of only two data centers, meaning that this cannot be used as a data source. (Hiekkanen ym. 2020).

[5] Until 10 October 2022 Finnish Data Center Forum FDCF.

[6] TOL 26, 58, 59–60, 61 and 62–63 in the Finnish Industrial Classification used in the original source. There is no difference in the standard international (Nace) and the Finnish classification at the 2-digit level.

2.3.3 Data on Waste Heat Potential

AFRY Management Consulting (2020) has estimated the utilized waste heat from data centers in Finland at 200 GWh/a, most of which is used in district heating networks. The total technical waste heat potential was estimated at 2 TWh/a but the study pointed out that the potential grows along with sectoral growth.

The waste heat potential estimate was based on the following business structure: max. ten over 5 MW (six owners, some with multiple data centers) and about 50 mid-sized 0.5–5 MW data centers. Total existing waste heat capacity was estimated at about 300 MW, which corresponds to about 2 TWh/a production, calculated with annual peak load utilization time of 6000 h/a.

3 Energy Consumption Trends and Environmental and Energy Efficiency Indicators for Data Centers

3.1 Global Trends

Figure 1 shows historic energy consumption in 2010 and 2018 by data center type and region. In addition, the figure shows energy consumption estimate should computing demand double from the 2018 level. Doubling the computing demand is not expected to increase energy consumption meaning that significant energy efficiency improvements are expected in the data center industry.

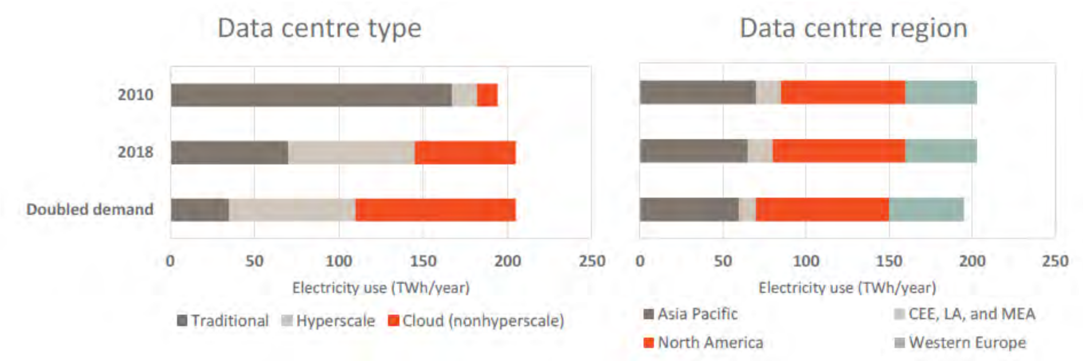

Figure 1. Historical and projected energy usage and energy usage under doubled computing demand (relative to 2018). Source: Cowi (2021) ref. Masanet et al (2020)

Figure 2 shows a synthesis on the internet traffic, data center workloads and energy consumption by data centers globally over the 2010–2020 period made by the International Energy Agency. While both internet traffic and data center workloads have multiplied over the ten-year period, energy use by data centers has changed very little meaning that energy efficiency of data centres has improved significantly. Globally, data centers used an estimated 200–250 TWh in 2020, or around 1% of global electricity use. (IEA 2021)

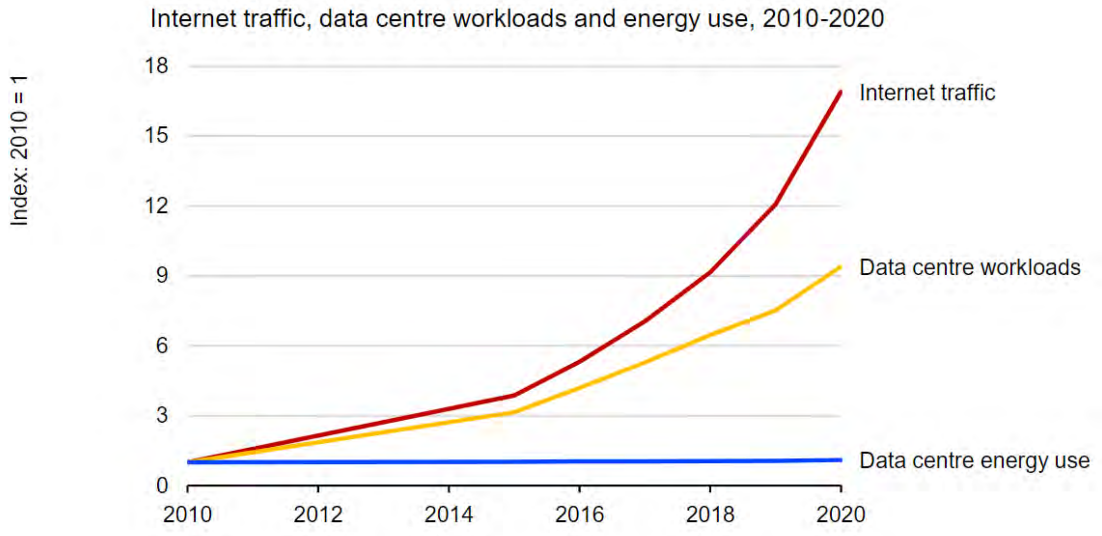

Figure 2. Global Data Center Energy Use Trends 2010-2020. Source: IEA (2021a) ref. Masanet et al. (2020); IEA (2021b); Cisco (2018); Cisco (2019).

Estimates of future energy consumption vary significantly from very moderate (e.g., IEA 2017–2020) to exponential growth (see Figure 3). Many of the earlier estimates have overestimated the demand in 2020; the realized level was 200–250 TWh while some future estimates for the year were in the range of 1000 TWh.

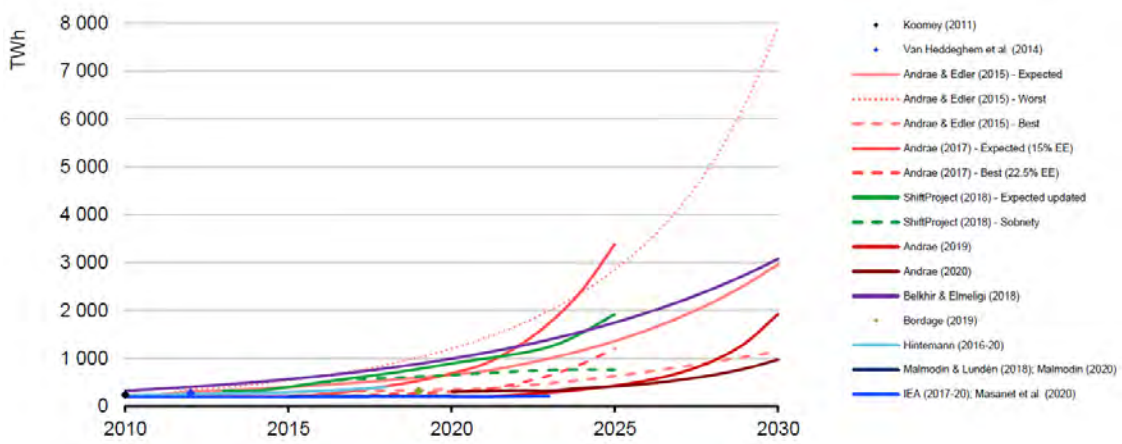

Figure 3. Estimates of Global Data Center Energy Consumption. Source IEA (2021a).

Figure 4 shows drivers which have increased service demand as well as drivers which have led to energy efficiency improvements. Installed storage capacity, data traffic and data center workloads as well as compute instances have all grown considerably. Energy efficiency has been improved by better average storage drive energy use (kWh/TB), average number of servers per workload and typical server power intensity (W per computation). Energy efficiency of IT hardware (servers, drives, network ports) has improved and servers have better power scaling capability (i.e., reducing power consumption during idle or low utilization). While earlier generations required 19 degrees operating temperature, newer servers work at 25–27 degrees which reduces cooling needs. While PUE (power usage effectiveness, i.e., less power for cooling) is paid a lot of attention, its impact on energy efficiency improvement has so far been minimal compared to these other factors. (IEA 2021)

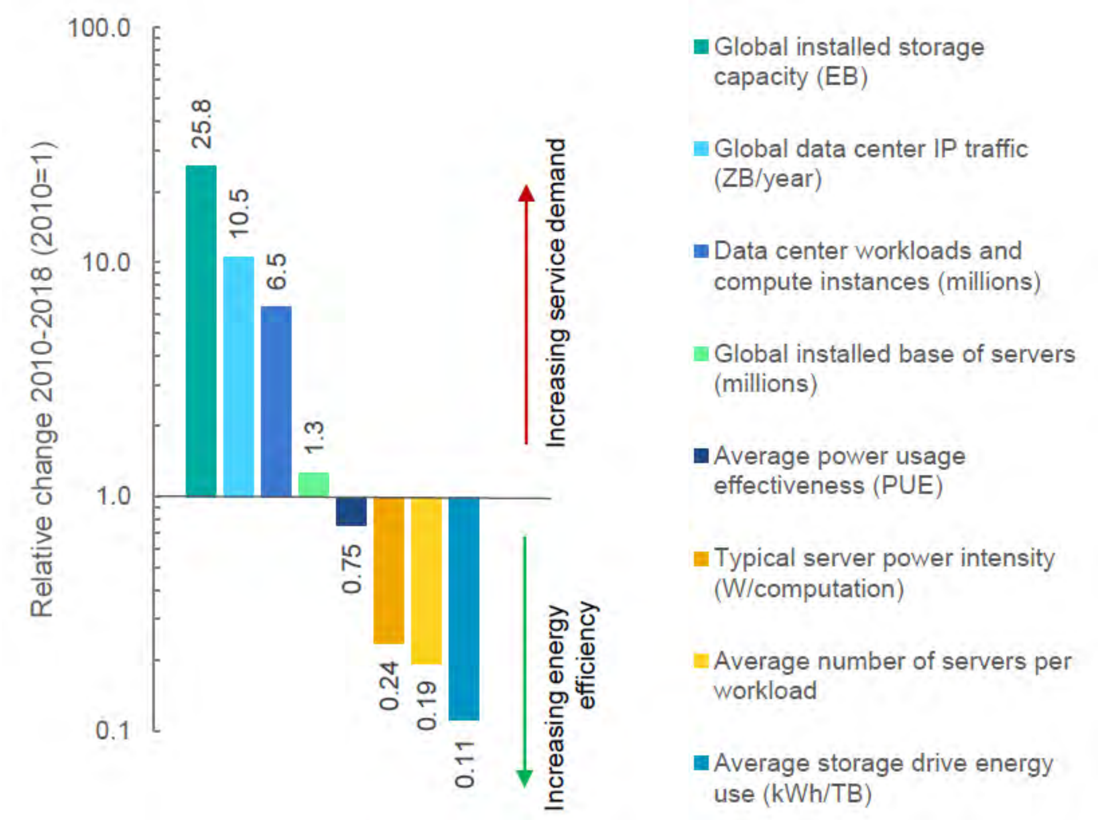

Figure 4. Drivers of energy consumption in data centers. Source: IEA (2020) ref. Masanet et al. (2020).

3.2 Environmental and Energy Efficiency Indicators for Individual Data Centers

3.2.1 Considerations in the Use of Indicators

Several indicators have identified to measure the environmental and energy efficiency performance of data centers – some more commonly used than others. Like in any other sectors, and possibly even more prominently in the data center sub-sector, there are numerous complexities in the use and interpretation of the indicators results. Koronen et. el (2020) summarises this very well: “Data centre energy efficiency is a complex issue that goes beyond the efficiency of the equipment. The resources needed to provide a certain digital service depend on the system’s performance, which is influenced not only by equipment design but also software architecture, resource allocation and operational set points. The complexity of the system and the difficulty in defining what is useful work (“one unit of digital service”) is why it is practically impossible to objectively measure and compare data centre efficiency using general metrics.”

In the existence of multiple sustainability goals and numerous indicators, there are also the questions of which targets to monitor, with which indicators, and how the results should be interpreted and weighted in the pursuit for sustainability. As water, along with energy, is also of interest - and sometimes there are trade-offs between these two resources - how should the total sustainability of a data center be evaluated and reported.

Once indicators have been chosen, there are also uncertainties related to their calculation. Despite best efforts in standardization, calculation of indicators in practice is always subject to making some decisions and choices, e.g., regarding system boundaries or presentation of results, which never allow indicators to be fully comparable across the whole industry.

3.2.2 Available Indicators

The IEA (2021a) and COWI (2021) have listed several indicators for measuring efficient use of resources, including energy, in data centers. These, along with some additional ones, are discussed hereunder.

Similar international and European standards describing key performance indicators have been published. The European standard EN 50600 is particularly important because the Recast of the Energy Efficiency Directive specifically refers to it in its requirements for indicator calculations (see Chapter 4.3.1) (European Parliament 2022).

- International standard ISO/IEC 30134 (Information technology — Data centres — Key performance indicators
    - Part 1: Overview and general requirements
    - Part 2: Power usage effectiveness (PUE)
    - Part 3: Renewable energy factor (REF/RES)
    - Part 6: Energy Reuse Factor (ERF)
    - Part 7: Cooling Efficiency Ratio (CER)
    - Part 8: Carbon Usage Effectiveness (CUE)
    - Part 9: Water Usage Effectiveness (WUE)
- European standard EN 50600 - Information technology. Data centre facilities and infrastructures:
    - Part 4-1: Overview of and general requirements for key performance indicators
    - Part 4-2: Power Usage Effectiveness
    - Part 4-3: Renewable Energy Factor
    - Part 4-6: Energy Reuse Factor
    - Part 4-7: Cooling Efficiency Ratio
    - Part 4-8: Carbon Usage Effectiveness
    - Part 4-9: Water Usage Effectiveness

Power Usage Effectiveness (PUE)

Perhaps the most used indicator is Power Use Effectiveness (PUE), which shows the relation of the total energy consumption of the whole data center to the energy consumption by the ICT equipment installed. PUE is defined in the international standard ISO/IEC 30134-3:2016, Part 2.

$$PUE = \frac{Total\ facility\ power}{IT\ equipment\ power}$$

The theoretical minimum of PUE is 1.00. PUE does not measure the efficiency of the ICT equipment but that of the surrounding building and infrastructure. Another problem is that companies do not calculate it in a completely uniform manner.

PUE values of particularly new data centers improved considerably about ten years ago, but development has stagnated (see Figure 5). In new facilities the theoretical minimum is becoming closer, and it is becoming more difficult to find savings opportunities (COWI 2021). On the other hand, improving the efficiency of old ones would require major overhauls (Uptime Institute 2021). Nevertheless, the overall energy efficiency has also improved as along with the shift from traditional data centers towards larger cloud and hyperscale data centers (COWI 2021). It is possible that PUE values may increase in the future due to increasing waste heat recovery if electricity consumption of heat pumps is included in the total facility power consumption. This, however, depends on the ownership arrangements of the heat pumps.

Some variants of the basic PUE are sometimes used. Partial PUE (pPUE) indicates the relative energy use of a given subsystem of the data center, such as the cooling system, and the energy use of its IT system. Another variation of this indicator accounts for shorter periods for which Interim PUE (iPUE) can capture energy intensity, for example, seasonally. A forward-looking indicator is the Designed PUE (dPUE), that sets the expected levels of energy intensity, e.g., after renovation. (Bergaentzlé & Madsen 2021)

Some examples of the prevailing PUE levels, as estimated and reported by the operators themselves, are given here:

- Uptime Institute (2021) reported the global average PUE at 1.57 in its 2021 survey.
- COWI (2021) reported the Nordic average at 1.71 based on data on 13 data centers.
- The global average of IBM:n data centers was 1.67 in 2020 (IBM 2022).
- The global average of Google data centers was 1.10 in 2020 (Google 2021).
- Data centers in Finland, some examples:
    - Google’s Tuike data center in Hamina 1.10 (Baxtel 2022).
    - Telia Pitäjänmäki in Helsinki 1.2 (Telia 2022)
    - CSC Colocation Data Centers in Kajaani, realized PUE of unit one was 1.03 and unit two 1.20 in 2020 (CSC 2022)

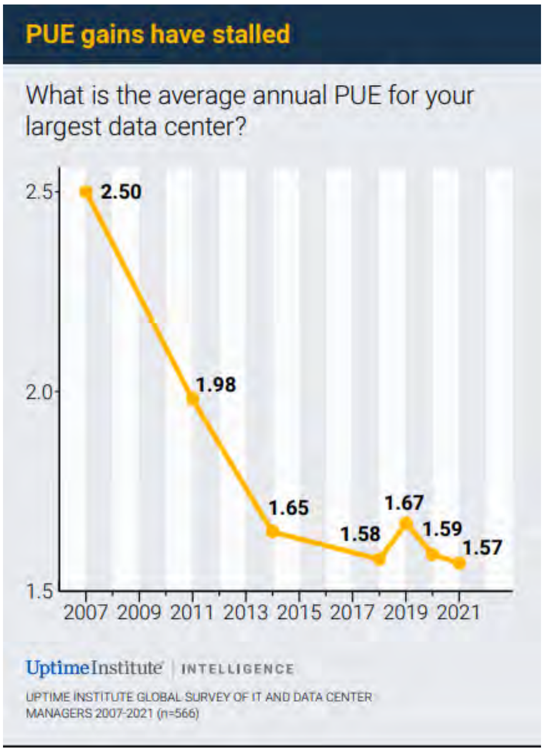

Figure 5. Survey results on PUE levels in 2007–2021. Source: Uptime Institute (2021)

Data Center infrastructure Efficiency (DCiE)

DCiE is a less commonly used measure than PUE but measures exactly the same phenomenon. The DCiE is the inverse of the PUE and is represented by a percentage. The unit of DCiE is a percentage.

$$PUE = \frac{IT\ equipment\ power}{Total\ facility\ power}$$

Renewable Energy Factor (REF)

REF (also referred to as RES) factor indicates the share of renewable energy used in relation to the total energy consumption by a data center. REF value 1.0 means that all used energy is renewable. REF is a normalized metric allowing the comparison of data centers of different sizes[7]. REF is defined in the international standard ISO/IEC 30134-3:2016, Part 3.

$$REF = \frac{Renewable\ energy\ used\ by\ the\ data\ center}{Total\ energy\ consumption\ by\ the\ data\ center}$$

[7] Guide to Environmental Sustainability Metrix for Data Centers

Energy Reuse Factor (ERF)

The calculation of Energy Reuse Factor (ERF) is defined by standard ISO/IEC 30134-6:2021. It is the relation of utilized waste heat outside the data center to total energy consumption by the data center. It is basically a number between 0 and 1, where 0 means that there is no recovery of waste heat and 1 refers to full recycling of energy. Oftentimes, waste heat is recovered into local district heating system.

$$ERF = \frac{Reuse\ energy\ outside\ of\ the\ data\ center}{Total\ energy\ consumptin\ by\ the\ data\ center}$$

Energy Reuse Effectiveness (ERE)

Tax legislation in Finland sets requirements for Energy Reuse Effectiveness (ERE), which is not defined in international standards as ERF is (see Chapter 4.5 for information on the Finnish tax legislation). However, it too takes simultaneously into account the impact of energy efficiency and waste heat recovery.

If energy efficiency of a data center is improved, i.e., energy consumption by infrastructure declines or amount of recovered energy increases, ERE factor diminishes.

$$ERE = \frac{IT + Infrastructure - Recovery}{IT}$$

Cooling Effectiveness Ratio (CER)

CER indicates the energy efficiency of the cooling system of a data center. It is defined in standard EN 50600-4-7:2020 (Information technology - Data centre facilities and infrastructures - Part 4-7: Cooling Efficiency Ratio).

$$CER = \frac{Q(removed)}{E(cooling)}$$

Where,

Q(removed) = the total amount of heat removed from the data center (annually) in kWh

E(cooling) = the energy consumption (annually) of the cooling systems in kWh

Carbon Usage Effectiveness (CUE)

CUE factor has been developed to monitor and evaluate greenhouse gas emissions from data centers. It is calculated by dividing carbon dioxide ($CO_{2\ eq}$) emissions caused by total energy consumption of the data center by energy consumption of the IT equipment. The lower the CUE factor is, the better. The ideal value is 0, which means that there are no carbon emissions.

$$CUE = \frac{CO_2\ emitted\ (kgCO_2eq)}{unit\ of\ energy\ (kWh)} \times \frac{Total\ Data\ Center\ Energy\ Consumption}{IT\ Equipment\ Energy}$$

The total data center energy consumption and IT equipment are exactly the same as in the PUE calculation. Therefore, the formula can also be simplified in the following manner:

$CUE = CEF \times PUE$, where CEF is the carbon emission factor or used energy (kg CO_{2eq}/kWh)

Water Usage Effectiveness (WUE)

Traditionally data centers require water for cooling – an estimated 25 million liters of water each year for a 1 MW data center and cooling is just one function for which data centers consume water (Sharma 2022).

Water Usage Effectiveness (WUE) relates water consumption of a data center to energy used by IT equipment; the unit is m^3/kWh. WUE is defined in the international ISO/IEC 30134-9:2022 which further classifies water usage into three categories: potable water, non-potable water and recycled water. WUE allows the comparison of data centers of different size categories.

The lower limit of WUE is 0, which means that there is no water usage in the data center operations. There is no theoretical upper limit to the WUE factor.

WUE covers only the end-use phase of the life cycle of the data center and IT equipment as more detailed life cycle analysis appears to be complicated.

$$WUE = \frac{Annual\ water\ usage}{IT\ equipment\ energy}$$

Power to Performance Effectiveness (PPE)

Power to Performance Effectiveness (PPE) was created by Gartner (see, e.g., Gartner 2009) to help identify efficiency of the IT equipment which is not taken into account by PUE and DCiE. This measure addresses server usage to power usage which typically do not have a linear relationship. A server at 20% usage may use 80% of its potential power draw. PPE "measures server performance per kilowatt". (Brotherton 2013)

The PPE does not compare actual performance to hypothetical maximums, but rather is designed to allow the user to define their own optimal maximum performance levels, and then compare average performance against the optimum. The components observed are rack density levels, server utilization levels and energy consumption. (Gartner 2009)

As Brotherton (2013) points out, the obvious shortcoming of the indicator is that it is lacking widely published equation despite the many industry articles announcing its superiority over the PUE. Therefore, PPE appears to be an idea about an indicator rather than an actual working one.

Data Center Energy Productivity (DCeP)

DCeP measures the useful work produced in a data center in relation to the total data center energy consumption. The indicator can be used to investigate the productivity of either just one data center or be applied in comparisons. The productivity is affected, among others, by the number of applications used, workload, bit flow, calculation capacity of the servers and the assessment window. Using DCEP indicator requires good data of the equipment in use. (Salmi 2015)

$$DCeP = \frac{Useful\ work\ produced}{Total\ data\ center\ energy\ consumed\ producing\ this\ work}$$

Useful work is measured over a given time span called the assessment window. Energy consumption is calculated over the same assessment window using information on instantaneous power demand. The formula for useful work is the following (The Green Grid 2008):

$$\sum_{i=1}^{M} V_i \times U_i(t,T) \times T_i$$

Where,

M = the number of tasks initiated during the assessment window

V_i = normalization factor that allows the tasks to be summed numerically

T_i = 1 if task I completes during the assessment window, and = 0 otherwise

$U_i(t, T)$ = time-based utility function of each task, where

t = elapsed time from initiation to completion of the task, and

T = absolute time of completion of the task

Data Center Performance Per Energy (DPPE)

DPPE is an aggregate indicator proposed by Green IT Promotion Council[8] to measure the overall energy efficiency and use of green energy of data centers. It is composed of four sub-indicators, namely IT Equipment Utilization (ITEU), IT Equipment Energy Efficiency (ITEE), Power Usage Effectiveness (PUE) and Green Energy Coefficient (GEC). (Green IT Promotion Council 2012; Shiino 2010).

DPPE and its sub-indicators can vary considerably even among data centers operating under the same technical specifications depending on the operational environment and purpose. Furthermore, indicator values are affected by management of equipment even when data centers operate in similar environments and for same purposes.

$$DPPE = ITEU \times ITEE \times \frac{1}{PUE} \times \frac{1}{1 - GEC}$$

Where,

ITEU (IT Equipment Utilization) = total energy consumption (actual measured electric energy) in IT devices / total rated energy consumption IT devices (rated electric energy).

[8] The Japanese Green IT Promotion Council (GIPC) was in operation from 2008 to 2012 and it has been succeeded by the Green IT Promotion Committee. It promotes green IT products (devices, solutions, and services) as well as discussion on the regulations and the subsidy system regarding the introduction of green IT products, discussion on the potential of energy conservation, international standardization of the energy efficiency metrics of data centers and carries out public awareness activities in Japan and abroad.

Actions: Efficient operation of IT devices: enhancing operating rates and reducing the number of operating devices through consolidation, virtualization, and other measures.

ITEE (IT Equipment Energy Efficiency) = total rated capacity of IT devices (rated) / total rated power (rated power) of IT devices. Actions: Introducing more advanced energy-saving IT devices.

PUE (Power Usage Effectiveness) = total energy consumption of the data center / total energy consumption in IT devices. Actions: Reducing energy consumption at the facility through various measures, including sophistication of air-conditioning systems and power source switching systems and utilizing the natural environment.

GEC (Green Energy Coefficient) = energy generated from green energy sources (natural energy sources such as photovoltaic and wind power) (actual measurement) / total energy consumption at the data center (actual measurement). Actions: Installing green energy generation equipment, including photovoltaic, wind, and water-power systems.

4 Energy Efficiency Efforts

This chapter gives an overview of both policies and measures as well as various commitments and activities taken by companies operating data centers.

There are international, European and national energy efficiency measures in place addressing energy efficiency of data centers.

4.1 International Initiatives

The Certification of Energy Efficiency for Data Centers (CEEDA)[9], is a global assessment and certification program designed to recognize the implementation of energy efficiency best practices in operating data centers. It is largely based on specifications drawn from European Code of Conduct but also from ASHRAE[10], Energy Star, ETSI[11], and The Green Grid. Only In Finland, Telia Helsinki Data Center participates in this scheme.

The Green Grid (TGG)[12] is an open industry consortium of data center operators, cloud providers, technology and equipment suppliers, facility architects, and end-users. It works globally to create tools, provide technical expertise, and advocate for the optimization of energy and resource efficiency of Data Center ecosystems.

The Energy Star Score for Data Centers applies to spaces specifically designed and equipped to meet the needs of high-density computing equipment such as server racks, used for data storage and processing. The objective of the Energy Star score is to provide a fair assessment of the energy performance of a property relative to its peers, considering the climate, weather, and business activities at the property. The current score calculation rules were published in 2018 and the number of US data centers with a rating is 214[13].

Leadership in Energy and Environmental Design (LEED), developed by the US Green Building Council, is a set of rating systems for the design, construction, operation and maintenance of green buildings. It is globally the most used environmental classification scheme for buildings. The certifications come as Silver, Gold and Platinum, and the highest Platinum certification indicates the highest level of environmentally responsible construction with efficient use of resources. Some data centers in Finland have acquired LEED certification.

The Tier Classification System[14] operated by the Uptime Institute has been running for over 25 years. Over 2500 certificates have been issued based on performance evaluations and site visits. There are no participants from Finland. Other data center tier classification systems are described in standards ISO 22237-1-7:2018 and DIN EN 50600-1-7.

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[9] CEEDA homepage. Participant listing.
[10] ASHRAE
[11] ETSI (An European Standards Organization dealing with telecommunications, broadcasting and other electronic communications networks and services.)
[12] The Green Grid.
[13] Energy Star Score for Data Centers . Energy Star rated data centers in the US.
[14] The Tier Classification. Participant list.

In addition to standards regarding performance indicators for data centers (see Chapter 3.2.2), there is the more overarching management standard "Information technology - Data centre facilities and infrastructures - Part 3-1: Management and operational information" (EN 50600-3-1) from 2016. The primary focus of this standard is the operational processes necessary to deliver the expected level of resilience, availability, risk management, risk mitigation, capacity planning, security and energy efficiency.

4.2 Existing European Policies and Measures

The Ecodesign Directive[15] set first regulations for computers and computer servers in 2013[16]. It was extended to servers and storage devices in 2019, and further amended in 2021. The regulation sets rules on energy efficiency, such as minimum efficiency of the power supply units and minimum server efficiency in active state, maximum consumption in idle state and information on the product operating temperature. The European Commission presents an estimate that switching to products that comply with the eco-design rules will lead to electricity savings of up to 9 TWh/year. Koronen et al. (2020) points out that regulating the energy efficiency of data center servers and storage devices under the Ecodesign Directive is more difficult than regulating many other product groups because the development of the technology is faster, and the operating modes of servers and storage devices are more complex. Although the Directive covers individual equipment that is used in data centers, the overall efficiency of any facility is not guaranteed (Bertoldi et al. 2017).

Data center operators and trade associations are committed to the European Green Deal[17] which is a self-regulatory initiative, basically a voluntary agreement between the industry and the European Commission, launched in January 2020. The initiative may be signed by trade associations representing data center operators (Pact Associations) and companies that own or operate data centers within the European Union (Pact Operators[18]). In Finland, the signatory Pact Association is the Finnish Data Center Association and so far, there are no Finnish Pact Operators although some international data center companies operating in Finland are listed. Signatories of the initiative are granted the right to use the Climate Neutral Data Centre stamp if they comply with all the engagements.

The commitments for energy efficiency, energy supply and water use in the Green Deal are:

- By 1 January 2025 new data centers operating at full capacity in cool climates will meet an annual PUE target of 1.3, and 1.4 for new data centers operating at full capacity in warm climates. Existing data centers will achieve these same targets by 1 January 2030. These targets apply to all data centers larger than 50 kW of maximum IT power demand.
- In recognition of the European Commission's interest in creating a new efficiency metric, trade associations will work with the appropriate agencies or organizations

[15] European Commission: Eco-Design of servers and data storage products
[16] Ecodesign requirements for computers and computer servers, 2013
[17] Green Deal for data centers
[18] List of Pact Operators

toward the creation of a new data center efficiency metric. Once defined, trade associations will consider setting a 2030 goal based on this metric.

- Data center electricity demand will be matched by 75% renewable energy or hourly carbon-free energy by 31 December 2025 and 100% by 31 December 2030.
- By 1 January 2025 new data centres at full capacity in cool climates that use potable water will be designed to meet a maximum WUE of 0.4 L/kWh in areas with water stress. The limit for WUE can be modified based on climate, stress and water type to encourage the use of sustainable water sources for cooling. By 31 December 2040, existing data centres that replace a cooling system will meet the WUE target applied to new data centres.

The European Code of Conduct for Data Centers (EUCoC)[19] is an initiative launched by the European Commission in 2008 for promoting the sustainability of the data center industry. Joining the scheme is voluntary but those joining commit themselves to ambitious voluntary standards, implementing an energy audit and to continuously identifying and implementing energy saving opportunities. They collect energy consumption data monthly and report it annually in a data sheet to the European Commission DG JRC.

The initiative publishes annually a Best Practices Guideline for the industry[20]. In Finland, the only participant to the Code of Conduct is one IBM data center[21].According to the Finnish Data Center Association, the industry association in Finland, the Code of Conduct is seen as a good general guideline in the data center industry but opting in has been low because there has been no particular benefit of joining the scheme nor there is a disbenefit of not doing so. Furthermore, there is a multitude of sustainability benchmarking schemes for the sector internationally as shown hereunder. It is unclear whether the Code of Conduct will have any major role due to the launch of the Green Deal and once the data collection requirements of the proposed EED Recast will be implemented (see Chapter 4.3).

European Commission's delegated regulation for the EU Taxonomy (EU 2021/2139)[22] addresses "Data processing, hosting and related activities", by requiring an audited compliance with the EUCoC. Data centers shall implement all relevant 'expected practices' listed in the most recent version. However, alternative best practices from the EUCoC or other equivalent sources may be identified as direct replacements if they result in similar energy savings.

European Commission has published green public procurement criteria for data centers, server rooms and cloud services[23]. The use of these criteria is voluntary for the Member States. There is anecdotal evidence that the European criteria are not commonly used, and some countries have published their own criteria where they try to address the shortcomings of the common ones.

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[19] EU Code of Conduct for Data Centre Energy Efficiency
[20] 2022 Best Practice Guidelines for the EU Code of Conduct for Data Centre Energy Efficiency
[21] Code of Conduct participants.
[22] Commission Delegated Regulation (EU) 2021/2139
[23] EU green public procurement criteria for data centres, server rooms and cloud services and JRC's study (2020) on the criteria

4.3 Data Center Obligations in the Proposed Energy Efficiency Directive Recast

The Energy Efficiency Directive (EED) of 2012 and its revision 2018/2002 did not have any specific provisions for data centers. In contrast, the ongoing update EED Recast will regulate data collection on the energy efficiency of data centers and set obligations regarding waste heat.

Because the Recast is still under preparation, proposals made in the different phases are described hereunder as it is not known yet what the final formulation will be. The trialogue between the European Parliament, Council of the European Union and the European Commission on the final proposal is ongoing in late 2022.

Chapter 4.3.1 hereunder discusses collection of energy efficiency indicators, Chapter 4.3.2 waste heat and Chapter 4.3.3 other provisions for data centers (energy management along with energy audits) in the EED Recast proposal.

4.3.1 Energy Efficiency Indicators and Monitoring in the EED Recast

European Commission's Proposal of the EED Recast, 14 July 2021

The European Commission published a recast proposal of the Energy Efficiency Directive (EED) on 14 July 2021 (European Commission 2021). According to Art 11(10), starting on 15 March 2024 and every year thereafter, owners and operators of every data centre in their territory with a significant energy consumption should make publicly available information set out in of Annex VI, which Member States shall subsequently report to the Commission.

Annex VI(2) in the proposal contains minimum requirements for monitoring and publishing the energy performance of data centers. It says: "The following minimum information shall be monitored and published as regards the energy performance of data centres referred to in Article 11(10):

a) the name of the data centre; the name of the owner and operators of the data centre; the municipality where the data centre is based;
b) the floor area of the data centre; the installed power; the annual incoming and outgoing data traffic; and the amount of data stored and processed within the data centre.
c) the performance, during the last full calendar year, of the data centre in accordance with key performance indicators about, inter alia, energy consumption, power utilisation, temperature set points, waste heat utilisation, water usage and use of renewable energy."

The level of "significant energy consumption" was not defined in the text. However, Article 31 stipulates the following: "The Commission is empowered to adopt delegated acts in accordance with Article 32 to supplement this Directive by establishing, after having consulted the relevant stakeholders, a common Union scheme for rating the sustainability of data centers located in its territory. The scheme shall establish the definition of data center sustainability indicators, and, pursuant to paragraph 9 of Article 10 of this Directive, define the minimum thresholds for significant energy consumption and set out the key indicators and the methodology to measure them."

Council of the European Union, 27 June 2022

On 27 June 2022 the Council of the European Union adopted the EED Recast proposal along with Art 11a (1) with the same contents as in Art 11(10) in the proposal of 14 July 2021. According to a footnote, the Commission was currently working on the concept of significant energy consumption for data centers, i.e., the question of "significant consumption" remained open. The outcome of this work may be part of the legislative text or a delegated act at a later stage. The obligations do not concern data centers used or providing their services exclusively with final purposes for defense, civil security and protection of population. By 30 June 2024, the Commission shall establish an EU database on data centers that includes information communicated by Member States in compliance with Annex VI (see Commission's proposal above). The EU database shall be publicly available. (European Council 2022)

European Parliament, 14 September 2022

On 14 September 2022 the European Parliament made amendments to the proposed EED Recast. In Article 11a one of the major amendments is setting 100 kW power threshold, in particular in the ICT sector, for the data reporting obligations.

It stipulates that the Commission shall adopt guidelines on monitoring and publishing the energy performance of data centres. Those guidelines shall contain harmonised definitions for each item of information as well as a uniform measurement methodology, reporting guidelines and a harmonised template for the transfer of the information to allow for consistent reporting across all Member States.

Parliament's amendment is the first EED Recast proposal that explains the potential usage of the data to be collected: "By 15 March 2025, the Commission shall assess the available data on the energy efficiency of data centres submitted to it by the Member States pursuant to paragraph 2 and shall submit a report to the European Parliament and the Council. The report shall be accompanied, if appropriate, by a proposal on further measures to improve energy efficiency, including on establishing minimum performance standards and an assessment on the feasibility of transition towards net-zero emission centres, in close consultation with the relevant stakeholders. Such a proposal may establish a timeframe within which existing data centres are to be required to meet minimum performance standards."

Annex VIa restates the exception for data centers related to national security and defense introduced by the European Council in June 2022. Provisions for data collection of ingoing/outgoing data have changed in the version adopted by the Parliament; this information only needs to be reported if available. Yet another change concerns reporting the amount of data stored and processed within the data center; this only shall be reported when this affects the energy consumption of the data center.

While the Commission's proposal of July 2021 and the European Council's version of June 2022 leave the list of key indicators to be collected open, the Parliament lists key indicators in Annex VIa. These key indicators shall be reported until the Commission delegated act on the matter.

- (i) Power Usage Effectiveness (PUE), according to CEN/CENELEC EN 50600-4-2
- (ii) Renewable Energy Factor (REF), according to CEN/CENELEC EN 50600-4-3
- (iii) Energy Re-use Factor (ERF), according to CEN/CENELEC EN 50600-4-6
- (iv) Cooling Effectiveness Ratio (CER), according to CEN/CENELEC EN 50600-4-7
- (v) Carbon Usage Effectiveness (CUE), according to CEN/CENELEC EN 50600-4-8
- (vi) Water Usage Effectiveness (WUE), according to CEN/CENELEC EN 50600-4-9

Questions Arising on the Implementation of the EED Recast Proposal

The reporting guidelines to be published by the Commission appear to be an important document in the implementation. It is important that these are published in a timely manner and will be clear enough. Practical experience from other EED processes, such as guidelines for calculation of energy savings, has shown the difficulty of harmonization.

Before the data collection starts, there are several open questions related from the administrative point of view:

- How the data will be collected? Is a common national database needed in addition to Commission's template?
- Who collects the data?
- How to ensure that all obligated parties report the data? What happens in a case of non-compliance?
- How should the exemption to data center related to national security and defense interpreted?
- How to justify non-reporting, e.g., data stored and processed within the data center on the grounds that it does not affect the energy consumption of the data center?
- Should there be quality control of the data and how this should be implemented?
- What is the administrative burden / resources needed for data collection?
- How, when and by whom will the data be reported to the Commission's database?

In Commission's and Council's drafts particularly the requirements to report "the annual incoming and outgoing data traffic and the amount of data stored and processed within the data centre" appeared difficult to implement. Oftentimes data center operators do not possess this data and it would take years to include the reporting requirements in the client contracts. Therefore, Parliament's formulation to report this data "when available" appears practical. Similar difficulties would have been associated with requirements to report stored data.

Finnish Industry Views on the EED Recast Proposal

The Finnish Data Centre Association, the industry association in Finland, was contacted to provide industry's insights to the proposed data collection in the EED. The following box contains FDCA's viewpoints as of November 2022.

Box 1

Finnish Industry Views on Monitoring and Indicators in the Proposed EED Recast

The Finnish Data Centre Association (FDCA), i.e., the national industry association, has been consulted to get industry views on the proposed data collection in the Energy Efficiency Directive (EED). FDCA reported the following viewpoints for data center provisions in the EED Recast:

The name of the data center; the name of the owner and operators of the data center; the municipality where the data center is based:
In practice, data centers are buildings or occupy part of a building listed in the building registry which contains basic data such as name of the property, floor area, owner etc. Property may be owned by a real estate company which rents the space to the data center operator. There is no known way to identify properties occupied by data centers in the building registry except, possibly, when the buildings are used by only a data center company.

The floor area of the data center:
Although building registry includes data on floor area of the building, this does not equal to the floor area occupied by the data center as usually there are other operations in the building. The correct metrics for data center floor area is so-called "white space", which is specifically the space used by the data center.

Temperature set points:
The requirement to report temperature set points is confusing because it is not clear how this is indicates energy efficiency levels. Simple set points tell very little without more detailed information on the cooling systems and mechanisms. Energy efficiency of cooling can be measured with PUE.

Cooling Effectiveness Ratio:
The Cooling Effectiveness Ratio (CER) is somewhat problematic performance indicator. Like PUE, CER is only suitable for measuring the efficiency of a cooling system in a real data center environment or installation. It cannot be applied to a component or infrastructure. To illustrate this – the CER only relates to the efficiency of the cooling system in a defined data center; the PUE relates to the efficiency of an entire data center. The CER cannot be used to make comparisons between different data centers. Also implementing CER in monitoring and measurements will impose costly and burdensome additional instrumentation to existing data centers.

Source: The Finnish Data Center Association (FDCA)

4.3.2 Waste Heat in the EED Recast Proposal

The European Commission published a recast proposal of the Energy Efficiency Directive (EED) on 14 July 2021 (European Commission 2021). Proposed EED Article 24(4) establishes obligations regarding waste heat from data centers:

> "In order to assess the economic feasibility of increasing energy efficiency of heat and cooling supply, Member States shall ensure that an installation level cost-benefit analysis in accordance with Annex IX is carried out where the following installations are newly planned or substantially refurbished:
>
> …
>
> d) a data center with a total rated energy input exceeding 1 MW level, to assess the cost and benefits of utilizing the waste heat to satisfy economically justified demand, and of the connection of that installation to a district heating network or an efficient/RES-based district cooling system. The analysis shall consider cooling system solutions that allow removing or capturing the waste heat at useful temperature level with minimal ancillary energy inputs.
>
> For the purposes of assessing on-site waste heat for the purpose of points (b) to (d), energy audits in line with Annex VI may be carried out instead of the cost benefit analysis set out in this paragraph."

The Recast proposal adopted by the Council of the European Union on 27 June 2022 repeats analytical requirements for data centers with power demand exceeding the 1 MW threshold presented in Commissions proposal of June 2021. (European Council 2022)

On 14 September 2022 the European Parliament made amendments to the proposed EED Recast. Article 34(3a) establishes a lower threshold of 100 kW: "Member States shall ensure that a data centre with a total rated energy input exceeding 100 kW utilises the waste heat or other waste heat recovery applications unless it can show that it is not technically or economically feasible in accordance with the assessment referred to in paragraph 4."

Paragraph 4 describes the assessment requirements in more detail: "In order to assess the economic feasibility of increasing energy efficiency of heat and cooling supply, Member States shall ensure that an installation level cost-benefit analysis in accordance with Annex X is carried out where the following installations are newly planned or substantially refurbished and their material costs have not yet been incurred:

> (d) a data centre with a total rated energy input exceeding 100 kW level, to assess the technical feasibility, cost-efficiency and impact on energy efficiency and local heat demand, including seasonal variation, of utilising the waste heat to satisfy economically justified demand, and of the connection of that installation to a district heating network or an efficient/RES-based district cooling system or other waste heat recovery applications. The analysis shall consider cooling system solutions that allow removing or capturing the waste heat at useful temperature level with minimal ancillary energy inputs."

The initially proposed threshold for the analysis, 1 MW, is higher than the 0.5 MW limit set in the Finnish tax legislation for data centers to qualify for lower electricity taxes provided that they meet with certain requirements (see Chapter 4.4). However, the threshold proposed by the European Parliament 100 kW is considerably lower. The view of the district heating industry is that the economically feasible level is about 300 kW of constant heat production.

The proposed requirements are not particularly difficult to meet as the feasibility of waste heat utilization is already considered in a routine manner particularly in new facilities. In the existing ones, their location vis-à-vis district heating networks or other potential heat users is a dominant factor in the development of waste heat projects.

4.3.3 Energy Management Provisions in in the EED Recast Proposal

One provision in the Parliament's amendment of 14 September 2022 is that Member States shall encourage owners and operators of every data center in their territory with an installed IT power demand equal to or greater than 1 MW to take into account the best practices referred to in the most recent version of the European Code of Conduct on Data Centre Energy Efficiency, or in CEN-CENELEC document CLC TR50600-99-1 "Data centre facilities and infrastructures - Part 99-1: Recommended practices for energy management", until the entry into force of the delegated act adopted pursuant to Article 31(3) of this Directive.

Article 11 includes provisions for energy management and energy audits for all enterprises subject to certain energy consumption thresholds. An energy management system, to be certified by an independent body, is required of companies with average annual energy consumption higher than 100 TJ (≈ 27 800 MWh) from 1 January 2024 and of those consuming over 70 TJ (≈ 19 400 MWh) from 1 January 2027. When energy management system is not implemented, an energy audit is required of companies with average annual anergy consumption higher than 10 TJ (≈ 2 900 MWh) from 1 January 2024 and higher than 6 TJ (≈ 1 700 MWh) from 1 January 2027.

4.4 Proposed New European Policies and Measures

A new EU Action Plan, Digitalising the Energy System, was published on 18 October 2022. Chapter 6.3 of the Action Plan discusses energy efficiency and other environmental considerations related to data centers. (European Commission 2022)

Some of the actions listed in the Action Plan are included in the proposed Recast of the Energy Efficiency Directive (EED) (see Chapter 4.3). However, there are some additional ones.

Probably the most notable new energy efficiency measure is that by 2025 the Commission will introduce an environmental labelling scheme for data centers, building on the monitoring and reporting requirements for energy consumption for data centers as proposed in the review of the EED.

Other measures address updating and extending the Ecodesign rules as well as exploring reporting lines for indirect greenhouse gas emissions stemming from the purchase of cloud computing and data center services under the Corporate Sustainability Reporting Directive. Funds will be allocated for research and investment in storing waste heat from data centers. The Commission will launch a study on optimizing the overall integration of data centers in the energy and water systems.

4.5 National Policies and Measures in Finland

Finland's national Climate and Environmental Strategy for the ICT Sector was adopted on 9 March 2021 (Ministry of Transport and Communications 2021). The Strategy establishes measures for the energy efficiency, use of zero-carbon electricity sources as well as waste heat in the ICT infrastructure. The measures applicable for data centers are:

- Utilise best practices and recommendations to increase energy efficiency when designing and building new data centers and when maintaining, upgrading and operating existing ones. Develop new methods by making use of modelling and pilot projects as well as the potential of innovation funding.
- Develop energy-efficient cooling solutions for data centers by utilising pilot projects.
- Conclude energy efficiency agreements that include yearly reporting. Make use also of other instruments such as energy audits and energy management systems to make operations more efficient.
- Purchase zero-emission electricity and review the potential to increase renewable energy production through long-term power purchase agreements (PPA).
- Look into the possibilities of data centers and other telecommunications facilities of sufficiently high volume to take part in the electricity market.
- Encourage waste heat recovery at data centers of all sizes by means of taxation-based solutions.
- Pay attention to the potential for waste heat recovery at the early planning stage of data center placement and increase awareness of successful case examples.

A long-running national policy measure in Finland have been the voluntary energy efficiency agreements[24] first introduced in 1997. The ongoing third generation of agreements is running from 2017 to 2025 and it is one of Finland's main measures to fulfil the obligations set in Energy Efficiency Directive's Article 7. Only few data center operators (e.g., Telia and Elisa) participate into the agreements which the Strategy names as one of the measures to address energy efficiency in ICT infrastructure.

The Energy Audit Programme started in 1992 and subsidized energy audits were implemented by trained professionals widely in the services sector. The scheme is still in operation but has been by and large replaced by the mandatory energy audits required by the Energy Efficiency Directive among large companies.

Investment subsidies are available for the implementation of energy efficiency measures and for investments in renewable energy[25].

Energy efficiency requirements in the building regulations[26] apply in the whole services sector, but they have no actual impact on the data center industry. Until 2016, energy efficiency regulations for buildings excluded buildings with large generation of excess heat, including also

[24] Energy Efficiency Agreements in Finland
[25] Energy Aid
[26] Although building regulations are established nationally, there are certain requirement regarding them in the Energy Performance of Buildings Directive.

data centers. In the 2016 update this exemption of lifted, but data centers which are classified as part of the services sector, now belong in the category "other building types" where no cap for energy consumption per square meter is set.

Information measures to improve energy efficiency of heating, ventilation and air conditioning are implemented in accordance with the Energy Performance of Buildings Directive.

Energy taxation is an important energy efficiency steering instrument in Finland. Electricity taxation in Finland is composed of two categories and the tax level in the lower category is 30% lower than in the higher category. The lower category has been available for, e.g., energy intensive industry and large data centers (above 5 MW). As of 1 January 2022, a larger number of data centers are in the lower tax class provided that they comply with certain environmental requirements (see text box).

Box 2

Energy Efficiency Conscious Electricity Taxation of Data Centers in Finland

Amendment 22.12.2021/2015 to the energy taxation law lowered the power demand threshold for data centers to qualify for lower electricity class from 5 MW to 0.5 MW but with some energy efficiency requirements. The amendment took force on 1 January 2022 and concerns other than enterprise data centers. The law did not set new requirements for data centers which already belonged into the lower electricity tax category. The energy efficiency requirements are:

- The annual average ERE factor shall be under 0.90 in data centers with power demand 0.5-5 MW. The ERE factor measures energy re-use, i.e., the relation of non-used final energy consumption to the energy consumption by IT equipment. ERE = (Total energy consumption – Used waste heat) / Energy consumption by IT equipment.
- The annual average ERE factor shall be under 1.00 in data centers with power demand over 5 MW but under 10 MW. ERE requirements do not concern data centers with power demand exceeding 10 MW.
- If the utilization of excess heat is not feasible for technical or economic reasons, the PUE of the data center shall not exceed 1.20 after 31 December 2026 and 1.25 before that. PUE = Total energy consumption / Energy consumption by IT equipment.
- ERE and PUE factors shall be based on reliable and validated measurements.
- The Ministry of Finance is authorized to give Decrees for more detailed calculation and implementation principles.

Sources: Law 30.12.1996/1260 and amendment 22.12.2021/2015

In line with the carbon-neutrality objective of Finland in 2035, Low-Carbon Road Maps have been prepared in several sectors in co-operation by the government and industry companies. The results of the roadmap work will be utilized in the preparation of the Government's climate and energy policy, the targeting of RDI investments and the preparation of a sustainable recovery. One of the road maps is for the technology industry, which also includes the data center industry. According to the Road Map, energy efficiency of data centers is constantly improving but electricity consumption of data centers and data communications is estimated to increase significantly due to growing volumes. Waste heat is available in data centers, for example, but its exploitation is restricted by their location. (Ministry of Economic Affairs and Employment 2021)

4.6 Examples of Energy Efficiency Work at the Company Level

This chapter provides some examples of energy efficient practices implemented in recent years in the data center industry in Finland. They range from waste heat utilization to new data centers with extremely low PUE values.

Sector-integration, co-operation between different sectors such as the energy sector and different industries, is considered as necessary to increase efficiency and reduce greenhouse gas emissions. Use of waste heat from data centers in district heating networks is becoming increasingly common in Finland where there are district heating networks in over half of all the municipalities including all the larger cities. In the following, examples of such new projects in Helsinki, Kajaani, Seinäjoki and Espoo are given.

However, there are other emerging sector integration solutions as well. In the following an example of a distributed data center approach with local small scale heat utilization is given. Yet another example of environmental benefits of sector integration is data center participation in the Fast Frequency Reserve (FFR) to help in balancing of interrupted supplies of renewable electricity in the national grid.

Telia Data Center in Helsinki: Use of Waste Heat and Participation in the Fast Frequency Reserve
The Helsinki (Pitäjänmäki) Data Center of Telia, a telecom operator and ICT service company, was commissioned in 2019. The data center is the largest co-location data center in the Nordic Countries. From autumn 2022, excess heat from the data center flows into the district heat network operated by Helen, the local energy company, providing heating to over 20 000 dwellings. Carbon footprint is further reduced by using electricity produced by hydro and wind power. In the summer months, excess heat is used for production of domestic hot water for the district heat consumers.

Fingrid (national transmission network operator) runs the Fast Frequency Reserve (FFR) which balances the network, e.g., during interruptions in renewable electricity supply and in operation disturbances. In 2022, Telia data center in Helsinki became a balancing service provider in the FFR system through its UPS (Uninterrupted Power Supply) equipment; the contribution is several megawatts.

Figure 6. Telia Helsinki Data Center. Copyright Telia.

CSC LUMI Data Center in Kajaani

LUMI supercomputer, constructed for research computation needs in Kajaani, was taken into use in June 2022. It is Europe's most efficient supercomputer. Building the data center inside a closed paper mill reduced emissions of the construction phase by 80% compared to a green field project. The data center uses hydro power on site and planned PUE value is as low as 1.05. Excess heat, equivalent for 20% of district heat demand in Kajaani, is sold to the local district heat company. Using waste heat from the data center reduces carbon dioxide emissions by 12 400 tonnes per year.

Figure 7. LUMI Supercomputer. Copyright CSC, image Pekka Agarth.

Kuulea – Distributed Data Centers for both Data Processing and Local Heating

Kuulea[27] offers high-performance computing and heating services that are produced by utilizing the principles of the circular economy. Kuulea provides data center services where the specially manufactured servers used to process data are distributed in properties that require heating services. Heat that is generated as a by-product of data processing is utilized locally in the heating of the property. The heat is carbon neutral, because it is generated as a by-product of energy that has already been used once. Since the heat is utilized and fed to the heating system at the same location where it is produced, no heat transmission losses are caused. The system is at its best in places where heat is needed evenly throughout the year such as hotels, spas, shopping centers, swimming pools, industrial properties, and large housing companies.

Figure 8. Kuulea Distributed Data Centers with Heat Recovery. Image: Kuulea.

Large-Scale Waste Heat Project by Microsoft and Fortum in Espoo

Microsoft and energy company Fortum have launched a joint project whereby Microsoft will construct a new data center campus in the Helsinki Metropolitan Area and Fortum will invest in large-scale heat recovery into the district heat network. Only zero-emission electricity will be used, and surplus heat from the data centers will cover 40% of the heat demand of 250 000 district heat customers in Espoo, Kauniainen and Kirkkonummi. The associated carbon dioxide emission reduction is 400 000 tonnes per year. The transmission network operator Fingrid will make the necessary investments in the power network. The project will be globally the largest waste heat recovery project from data centers. (Microsoft 2022, Fortum 2022)

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[27] Kuulea heating

Figure 9. Large-Scale Waste Heat Project by Microsoft and Fortum launched in Espoo. Image: Fortum.

Waste Heat Demonstration Project in Seinäjoki

In January 2022, Ministry of Economic Affairs and Employment granted a 2.1 million euro investment subsidy to Kiinteistö Oy DC Seinäjoki for a demonstration project for recovering waste heat (63 GWh/a) from a data center and transferring it into the district heat network. The innovation aspect of the project is the technology used for recovering the heat; it allows the optimal use of heat in the district heat network. The technology has potential to be used in other new data centers as well. First, recovered heat will account for ten per cent of the district heat needs in the city of Seinäjoki but the objective is to increase the proportion to thirty per cent later.

Figure 10. Seinäjoki Data Parks' Future Site. Image: Tarmo Niemi/Yle.

5 Summary and Conclusions

5.1 Energy Efficiency Status of Data Centers in Finland

The data center industry has a significant green handprint enabling digital services and thus making a positive contribution towards low-carbon economy. It also has major potential in advancing integration with the energy sector thus entailing further environmental and other sustainability benefits.

Clients already put considerable pressure on the sustainability of the sector and there are a multitude of different voluntary sustainability schemes which can be used to demonstrate progress. However, at the same time the sector is also a considerable energy consumer, and it is difficult to judge how energy efficient it is. Although indicators to measure sustainability – including energy efficiency - are available, these are not yet publicly reported. This is expected to change in a couple of years (see Chapter 5.2).

After the energy tax revision in 2022 in Finland, hyperscale and co-location data centers have a good fiscal incentive to pursue energy efficiency, tap waste heat potentials and use renewable energy. However, this does not drive improvements in enterprise data centers which are typically less energy efficient than large commercially operating facilities. Nonetheless, current high electricity prices are likely to create a strong incentive for energy efficiency improvements throughout the sector.

The PUE levels of new data centers in Finland are typically very low and renewable electricity is used extensively. Using waste heat in district heating networks is becoming increasingly common but there is still some untapped potential.

Urban planning could be used to further facilitate waste heat utilization by identifying good sites for new data centers or data center campuses close to district heating networks. Another spatial and network issue is access to wind power. Wind power, which is an interesting source of renewable electricity for data centers, is being built in the west coast while many data centers are located in the southern part of Finland. Some bottlenecks have been identified in the transmission network to accommodate growing wind power production but reinforcing the network is expected to take several years.

While tapping the waste heat potential is one example of sector integration with the energy sector, offering network balancing services through Fast Frequency Reserve is another one, with first practical example in operation. Data centers also have some flexibility in timing their power demand which could be used to alleviate peak load issues in the power system. This may be important in the winter 2022–2023 when power cuts will be a real risk Finland.

New innovations are still emerging. One is distributed data center infrastructure within heat using properties which avoids heat transmission losses. It can also be a way to overcome some barriers with integration with the district heating systems as district heating companies typically consider 300 kW of constant heat supply as the minimum feasible threshold. Another innovation is moving to DC power distribution architecture within the data centers thus reducing the number of power conversions and associated losses.

One area where efficiency improvements could possibly be gained in the data center industry as a whole, is reduction of idle operation. Although clear improvements have taken place over the past ten years, literature still suggests that operators can save 10–15% of the electricity used in data centres by adopting better computing management strategies (Koronen e al. 2020 ref. Rong et al. 2016). Due to lack of data, it is impossible to say how acute the issue of idle operation is in Finland. Nonetheless, there is some evidence from Rittal that operation and maintenance of almost one third of all data centers in Finland is not at adequate level, which seems to apply mainly to enterprise data centers (Kullas 2021).

Measures taken in data centers only tackle part of the energy efficiency challenges of the ICT sectors. The other two interlinked areas are consumption of ICT services and infrastructures. Services provided to the users drive the data flows and capacity needs in data centers. Therefore, energy saving practices in these areas, such as green coding, are crucial.

5.2 Environmental Indicators for Data Centers

There is a multitude of different energy and other environmental indicators for data centers, some more commonly used than others. The existence of many indicators is logical as there are numerous environmental and resource efficiency objectives such as energy efficiency, use of renewable energy, making use of waste heat and efficient use of water. It is important to recognize possible trade-offs between the objectives and avoid sub-optimalization of just one objective.

One lesson learned from other sectors with longer tradition of benchmarking with indicators is that it is very important to compare alike with alike. Although data centers - or any other facility such as factories or supermarkets - may offer same services, the benchmarks should be rather similar in terms of size and other relevant specifications. Among the data centers this effectively means that hyperscale or large co-location data centers should not be compared with smaller enterprise facilities.

Another lesson is that the processes within the evaluation perimeter should be comparable. If electricity used by a heat pump for waste heat utilization is included in the energy balance of some operators, but not others, this can distort comparisons.

Calculation standards help in harmonization of the indicator calculations, but this is not necessarily adequate to ensure comparability as there is still often room for different interpretations. Verification processes by third parties can help in creating trust in the results.

Indicators are closely linked to the new European policy initiatives such as minimum performance standards for data centers (proposed in the EED Recast) and environmental labelling of data centers (vocalized in the 2022 EU Action Plan Digitalising the energy system).

The European Code of Conduct for Data Centers has remained as a rather small-scale scheme. However, recent political references to it both in EU Taxonomy and the EED Recast are likely to increase its status.

It will also be interesting to see whether the European Green Deal will attract wider participation. It also remains to be seen what the indicators will be to be developed within the Green Deal. Topics raised in the discussion are more integrated indicators which consider, e.g., sector integration as well as the need to monitor decoupling of greenhouse gas emissions from sectoral growth.

New Reporting and Other Requirements for the Data Center Industry

There are some new developments in energy indicators for the data center industry. A particularly important one is the mandatory data and indicator collection and publication in the proposed recast of the Energy Efficiency Directive.

The data center industry should be prepared to annually calculate and report several indicators starting at the latest on 15 March 2024 as required in the proposed Directive. These indicators are Power Usage Effectiveness (PUE), Renewable Energy Factor (REF), Energy Re-use Factor (ERF), Cooling Effectiveness Ratio (CER), Carbon Usage Effectiveness (CUE) and Water Usage Effectiveness (WUE). The requirements concern data centers with power needs above 100 kW.

Furthermore, new and substantially refurbished data centers with power need above 100 kW shall carry out a cost-benefit analysis on use of waste heat. Lastly, data centers with an installed IT power demand equal to or greater than 1 MW need to implement energy management in accordance with CEN-CENELEC document CLC TR50600-99-1 (Data centre facilities and infrastructures - Part 99-1: Recommended practices for energy management).

Publication of basic indicators, such as energy and water consumption, waste heat utilization and use of renewable energy creates a much better and transparent knowledge base on the industry for policy makers and clients than we have today. On the other hand, it provides the industry itself with a possibility to make sustainability improvements more visible in a way that positively builds up trust.

Despite significant positive viewpoints, there are some concerns in the EED requirements. It appears that collection of metering data of cooling will require large investments in existing facilities and periodic certification of the meters. Although the EED Recast draft has evolved into a more practical direction, there are still some concerns that indicators irrelevant in monitoring energy efficiency or monitoring data not possible to collect may be required. It is also not clear if extensive openness on data center’s locations and operations is sensible in the current geopolitical turmoil although EED proposal makes some exemptions for data centers used exclusively to defense, civil security, and protection of population.

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