An international policy-oriented workstream for energy efficiency of Data centres.

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ABSTRACT: Data centres (DC) are crucial infrastructure of an ever more digitalized world. The increasing demand of digital services for smart energy systems, automated production systems, autonomous transport, blockchain and artificial intelligence will have implications on the size, numbers and energy demand of data centers globally. Energy consumption of DCs is estimated to account for 1% to 1,5% of the worldwide electricity use (IEA 2022). This paper presents and discusses a new international policy-oriented Workstream focusing on energy efficiency for data centres. Its objectives are evaluating the different aspects of energy efficiency, developing harmonized efficiency metrics and policies to promote better monitoring, reporting, and management of energy use of the data centres.

1. INTRODUCTION

Data centres and wide area networks are complex systems connecting computers and other devices together on the internet. In particular, a data centre has one or various structures to accommodate, interconnect and operate information technology (IT) and network telecommunications equipment in a centralized way, which in turn provide data storage, processing and transport services (OVE 2022). The DC infrastructure also includes the building envelope, power and environmental controls which securely house the equipment, provide a reliable power supply and ensure a suitable operating environment, as shown in Fig. 1. The energy consumption of a DC is determined by the energy use of the IT hardware and supporting infrastructure, but also by how the equipment interacts and is being controlled (Wu et al. 2019).

Although the demand of digital services provided by DCs is rapidly increasing, the energy efficiency improvements, the purchase and use of renewable energy, and the broader decarbonization of electricity grids in many regions have helped maintain a moderate electricity consumption of DCs, accounting for around 1% to 1,5% of global electricity use (Kamiya 2021; IEA 2022). Different scenarios of global electricity use by DCs are discussed in Masanet et al. (2020) and show differences in the forecasted energy use up to 2030.

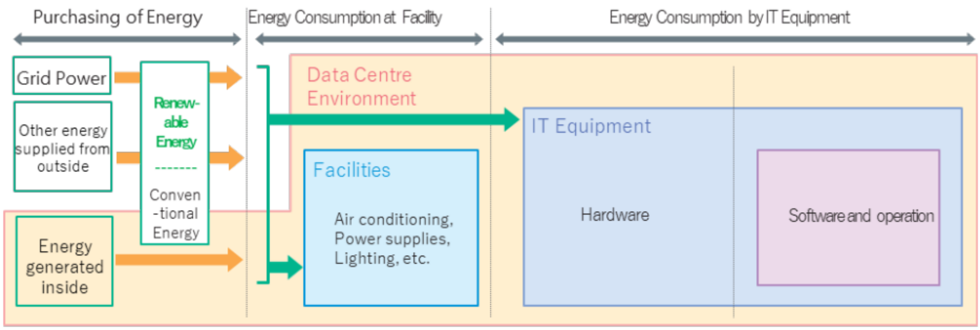

Fig. 1: Scheme of the data centre environment, including energy inputs (Wu et al. 2019).

In the case of Austria there is limited information on the energy use of DCs. A project of the Austrian Energy Agency presents the impacts of digitalization in various sectors (AEA 2022). The analysis shows estimates of energy consumption of the information and communication technology (ICT), on the basis of another study on DCs (carried out in Germany by Fraunhofer IZM in 2015), with trends extrapolated until 2040 for Austria. In the reference scenario, the final energy consumption is around 292 TWh; and around 4% to 10% of energy consumption could be saved in 2040 through digitization. However, the authors indicate that the increased use of ICT, data centers and telecommunications infrastructure can result in up to 2,3 TWh of additional energy consumption (Baumann et al. 2022a, Baumann et al. 2022b). Recent studies in neighboring countries also suggest that the data volume processed and stored in DCs will continue to increase. The electricity consumption of DCs and server rooms in Switzerland for 2019 accounted for between 3,3% and 4,1% of the total electricity consumption (Jakob et al. 2021). In Germany, the energy demand of servers and DCs increased by 7% year-on-year, equivalent to around 1 billion kilowatt hours (kWh) to 16 billion kWh in 2020 (DB, 2021). At European level the electricity consumed by DCs was estimated at 2,25% of the total EU electricity use in 2015, and this amount is expected to double by 2030 (Dodd et al. 2020).

To reach 2030 and 2050 greenhouse gas emission reduction targets, policy-makers are exploring suitable policies and approaches to increase the energy efficiency of DCs. This paper describes the activities of the Workstream energy efficiency of data centres of the Electronic Devices and Network Annex - EDNA (EDNA 2022). The goal of this international collaboration is to assist policy-makers in creating and improving energy efficiency policies tailored specifically to DCs, by carrying out specific activities, as presented in Fig. 2. Various activities under "Current status" are explained in the next sections. Other activities under "measures" and "impact/projections" will continue in 2023 and 2024, to include energy efficiency metrics and possible policies in EDNA´s Total Energy Model (Ryan et al. 2019; Díaz 2020, EDNA 2020).

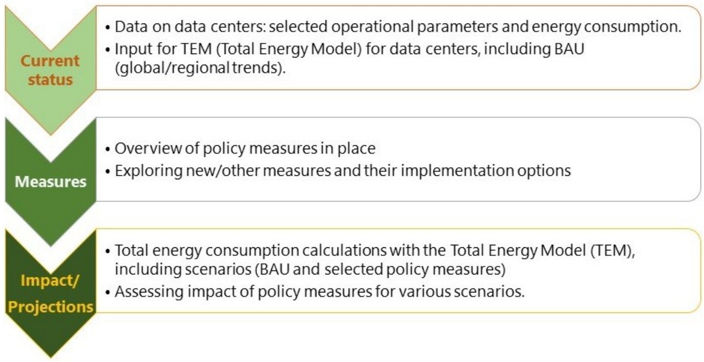

Fig. 2: Phases and activities of the Workstream on energy efficiency of DCs (EDNA 2022).

2. DEFINITION, CLASSIFICATION AND ENERGY USE TRENDS.

The activities under "Current status" explore the diverse definitions and classifications of DCs. This analysis also evaluates the energy use trends, and the data availability and quality of metrics and information. For policy-makers it is necessary to consider a suitable scope, boundaries, components and the relevant energy and material flows in a DC, when developing policy measures on energy efficiency. The definition proposed in this Workstream is: "A data centre is a structure, or group of structures, dedicated to the centralized accommodation, interconnection and operation of, **and including**, information technology (IT) and network telecommunications equipment providing data storage, processing and transport services together with all the facilities and infrastructures for power distribution and environmental control together with the necessary levels of resilience and security required to provide the desired service availability" (Harryvan 2023).

There are different classifications of DCs, according to the DC purpose, security level, physical size, accommodation, availability of service, provision of security, and objectives for energy efficiency. The most common aspects used by the industry to classify DCs are purpose, availability of service, and size. A suitable classification of DCs for policy-making purposes shall cover (most of) the entire market, and include sufficiently specific categories of DCs so that policies are effective. The classification developed in the Workstream, shown in Tab. 1, reflects the ownership and operation of the DC - building infrastructure, hardware and software (Harryvan 2023). It starts with the dedicated enterprise DCs, which are operated with the sole purpose of delivering and managing services for employees and customers. The co-hosting DCs follows. In this case, multiple co-hosting customers operate their own software and services through access to the network(s), servers, and storage equipment. Finally, in the co-location DCs the supporting infrastructure is provided as a service by the co-location provider, and the DC hosts the network(s), servers and storage equipment of many customers.

Tab. 1: Classification of DCs for the EDNA Workstream (adapted from Harryvan 2023).

	Responsible party for ownership/operation		
DC Category	Building supporting infrastructure	IT equipment	Software
Entreprise	Data centre owner		
Co-hosting	Co-hosting provider		Co-hosting customers
Co-location	Co-location provider	Co-location customers	

Trends of energy use of DCs were already discussed, from Masanet et al. (2020), Kamiya (2021), and IEA (2022); and will continue to be tracked due to the awareness that digitalization is driving the growth of DC services. Tab. 2 shows the energy use for the four major elements inside a data centre (IEA 2022). The energy use of the DC site infrastructure is mainly due to the energy demand for the cooling solution, and this cooling is needed to dissipate the heat losses of the IT equipment in order to maintain an appropriate range of operation of sensitive equipment.

Tab. 2: Energy use of DC elements (adapted from Harryvan, 2023).

Elements inside DC	Estimated energy use 2021 (TWh)
DC site infrastructure	59,0
Servers	109,0
Storage	19,0
Network	4,0

Harryvan (2023) indicates that the servers are responsible for over 80% of the total energy use of a DC, and their utilization and efficiency are very important for the overall energy efficiency of the DC. In the short-term IT systems will continue improving in capacity and efficiency, but these improvements will come at a slower rate compared with previous decades. The newer systems will most likely have higher energy demands, creating even more heat in a smaller space than current systems, and demanding an effective cooling; but more options could also emerge for using the waste heat, because e.g., liquid cooling delivers waste heat with a higher temperature.

3. METRICS FOR DATA CENTRE ENERGY EFFICIENCY

Industry specialists have developed different metrics to optimize operations and costs of data centres considering aspects related to the design and operations, such as building construction, power distribution, environmental control, telecommunications cabling and physical security. Metrics like the power usage effectiveness (PUE), IT equipment energy efficiency for servers (ITEEsv), and IT equipment utilization for servers (ITEUsv) are available and defined in the standard series ISO/IEC 30134 Information technology - Data centres - Key performance indicators (Parts 1 to 9). The power usage effectiveness (PUE) is the most common metric used for reporting and benchmarking the energy performance of DCs, and it is often also used for marketing. The PUE is a ratio which divides the total amount of power entering a data center facility by the power used by the IT equipment. PUE only expresses the overhead energy consumption for auxiliaries, compared to the IT consumption. PUE values towards 1.0 show better management of the whole DC infrastructure, but do not give insights into the performance of the IT equipment. Worldwide PUE improvements are slowing down for large DCs since 2014, and seems to be stalling at around 1,55 in 2022 (Uptime Institute 2022).

The EDNA Workstream experts analyzed and evaluated a number of DC metrics from standards such as CEN, CENELEC and ETSI in Europe, and IEC/ISO internationally, as well as metrics from DC associations and companies, and from regulatory programs in various (EDNA) countries. Two types of metrics - energy and functional, were identified and described in a comprehensive study (Viegand Maagøe 2022). The energy metrics provide information about how energy is consumed by specific equipment and systems, without considering the output or work delivered by the equipment/system or by the complete DC. The functional metrics consider the data processing, storage and transport (networking) services delivered by the DC. On the one hand, metrics for evaluating the performance of single IT equipment in data centres are already incorporated in European regulation, for example for enterprise servers and data storage products (OJEU, 2019). The measurement of the server efficiency in this regulation follows the standard EN 303 470: 2018-Environmental Engineering (EE); Energy Efficiency measurement methodology and metrics for servers. On the other hand, only two cases of single metrics for all the DC functions - the data centre performance per energy, from the Japanese Green IT Promotion Council; and the ICT capacity and utilization, from the Green Grid were identified. **Two new DC functional metrics** for use by policymakers were proposed by the Workstream (Viegand Maagøe 2022). The first one is the IT equipment average efficiency index (ITAEI), defined as the average used capacity divided by the average IT power used. The second metric is the data centre functional efficiency (DCFE), which evaluates the total work delivered and the total energy consumption of the DC during a reporting period. This metric focuses on the DC operation and all the energy consumed. These two proposed metrics require data on the used capacities and used power of servers, storage and network; and the work delivered by servers, cumulative storage and network used along a reporting period.

Two alternative DC energy metrics to assess energy wasted in servers and DCs were also defined by the EDNA Workstream. These are the server idle coefficient (SIC) and the data centre idle coefficient (DCIC). The SIC only targets servers and quantifies the percentage of energy spent on idle cycles. Idle is the process when the server has no useful workload to run. The DCIC extends the SIC to all the servers in the data centre, and it is a percentage of the energy use of the IT equipment that is used for idle in the

DC. The DCIC addresses the operation of the IT equipment by owners as well as the design of the equipment by manufacturers. Harryvan (2021) provided examples on the data needed from the server hardware platform to calculate the SIC, particularly data on CPU utilization and total power draw over regular intervals. This study analyzed the SIC and DCIC metrics for real server cases, and discussed optimization examples, such as the selection of equipment with low idle power draw and optimization of workloads.

4. POLICIES FOR ENERGY EFFICIENCY OF DATA CENTRES

Experts of the Workstream recognize that the DC is a complex system, with many and different (infrastructure and IT) sub-systems and components, where also the assembly plays a role on the energy performance of the system(s). The possible policy measures for regulating systems need to consider the scope, the addressees of the regulation, the energy efficiency metric(s) and requirements, and the performance assessment methods including testing or other alternatives. The development of regulations needs to go hand in hand with appropriate approaches for verification and enforcement (IEA 4E 2022). Brocklehurst (2021) completed a global overview on data centers. For data centres as a complete operational unit, direct energy efficiency regulations were lacking. Voluntary labels, rating and certification schemes for DCs, some of which include energy efficiency as a criterion, have been developed by different organizations. Other initiatives such as public sector procurement criteria, are also in place. Prior to the development of any policy option for DCs, data collection is an important and necessary step. Therefore, policy-makers need to consider a harmonized framework for the provision of information, which will enable access to the data for statistical and technical analysis of DC. This also means defining the parameters, the testing methods, sampling periods and/or the reporting periods for data collection for the different DC categories (Viegand Maagøe 2022). Attention shall be paid, for example, to co-location data centres, because the co-location providers may be able to set some requirements regarding IT hardware, but they may not know the energy efficiency and operational conditions of the hardware in the DC. Moreover, the co-location customers may not want the provider know to energy efficiency related information (Harryvan 2023). With such situations in mind, the proposal for the new EU Energy Efficiency Directive is a positive step, since it will probably be the first regulation to be implemented that requires DC owners and operators to publish data, which can in turn be used for evaluating metrics (Viegand Maagøe 2022).

5. SUMMARY AND OUTLOOK

The forecast for energy use by data centres is greatly dependent on the modeling scenarios, with a strong interplay between the impact of growth in energy demand and the efficiency gains. Future trends with impacts on energy use are the shifting of computing capacity, e.g., from enterprise to co-location DCs, the faster adoption of more efficient IT equipment (and also new technologies for cooling); deploying IT equipment and resilience levels for specific business cases, targeting the right utilization levels of the servers, networking and storage. Still, scenarios where energy use by DCs will continue to rise are more likely in the near future. This is why policy-makers started the international Workstream to promote energy efficiency policies for data centres (EDNA 2022). Suitable metrics for energy efficiency of DCs need to consider the scope (DC buildings, ICT equipment, power supply, cooling equipment, and integrated power and emergency generation equipment), as well as the role that strategies such as the use of waste heat and renewable energy can play in terms of energy efficiency, in addition to reducing greenhouse gas emissions, and enabling synergies with the infrastructure around the location of the DC. The metrics and policies need to be applicable to existing and future DC, and the lack of data on DCs shall not hamper policy development, but shall help identify the technical, confidentiality, organizational or other issues that limit data availability. This EDNA Workstream has defined new energy and functional metrics (4), which could serve for developing policy measures. The work will continue in 2023, to quantitatively model policy scenarios and their impacts, with selected metrics and by means of an expanded Total Energy Model (EDNA 2020).

ACKNOWLEDGEMENT:

This work is supported by the IEA Research Cooperation program of the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK), under the FFG Grant 890457.

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