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From power to heat: why the data center is the new light bulb

A data center does not convert electricity into "power". It converts electricity into digital services: storage, computing power, transactions, AI models, video, cloud software and communication. But physically, almost all the electricity that a data center uses eventually ends up as heat. This applies to servers, network equipment, storage, power supplies, UPS systems, fans, pumps and cooling. A small part leaves the building temporarily as an electromagnetic signal, light or sound, but that too eventually ends up almost entirely as heat in the environment.

The question is therefore not only: how much power does a data center use? The better question is: how much social value, digital performance and reusable heat do we get from each kilowatt hour?

That's exactly where the problem lies. The sector still often looks at PUE: Power Usage Effectiveness. PUE compares the total energy consumption of the data center with the energy consumption of the IT equipment. A PUE of 1.2 means that for every 1 kWh that goes to IT, another 0.2 kWh is needed for cooling, power distribution and supporting systems. PUE is useful, but limited: it says little about what the servers actually do, how much capacity remains unused, whether the residual heat is put to good use. The definition of PUE is explicitly focused on the relationship between total facility energy and IT energy.

This is where the comparison with the incandescent bulb arises. A traditional light bulb was long seen as normal: you put electricity in it and got light back. Until it became clear that about 90% of the energy was lost as heat and only about 10% was used as light. LED lighting fundamentally changed the perspective: no longer accepting that heat loss is part of it, but steering towards useful output per watt. According to the U.S. Department of Energy, LED bulbs use at least 75% less energy than incandescent bulbs, and incandescent bulbs emit about 90% of their energy as heat.

Data centers are now facing a similar turnaround. The old reflex is: more digital demand means more servers, more power, more cooling and therefore more grid capacity. The new reflex should be: how much digital performance do we deliver per watt, how much equipment is idle, how much heat can we reuse and does this data center fit at this location?

A data center is essentially an electrical heat source with digital bycatch — or, more positively, a digital factory that provides high-quality services while producing a continuous flow of heat. If that heat is blown into the outside air unused, it is a chain loss. If that heat is linked to homes, greenhouses, swimming pools, industry or low-temperature heat networks, a different story emerges. Then the data center becomes part of an energy chain instead of anisolatedenergy consumer.

For that, we have to measure differently. Not only PUE, but also server utilization, energy per workload, idle consumption, performance per watt, CO_2 intensity per hour, heat quality, temperature regime and actual heat supply to third parties. The European direction is also moving in this direction: the Energy Efficiency Directive introduces monitoring and reporting obligations for the energy performance of data centers, precisely because transparency is needed to assess energy use and environmental impact. The European Commission has also established an EU-wide system for data centre sustainability indicators, with reporting of key performance indicators.

The core is that we should no longer design data centers just as buildings, but as links in a chain. The choice of location then becomes strategic: not only close to fiber optics and electricity, but also close to heat demanders, sustainable generation, storage and flexibility. Cooling then becomes not only a cost item, but a design variable for heat reuse. IT equipment is then not only judged on availability, but also on useful performance per watt. Software is not only assessed on functionality, but also on energy behaviour.

The lesson of the LED is that real efficiency does not come from better ventilating away the loss, but by redesigning the system. In lighting, we switched from "heating a wire until it gives light" to semiconductor technology that produces much more focused light. In data centers, we have to move from "filling servers and dissipating heat" to "optimizing workloads, measuring energy in real time and making good use of residual heat".

Almost 100% of the power in a data center eventually becomes heat. That's no shame; it's physics. But it does become a problem if we treat that heat as waste, while society is struggling with grid congestion, energy prices, climate goals and heat demand.

The question for the coming years is therefore not whether data centers will be allowed to grow. The question is under what conditions. A data center that only requires electricity and discharges heat is becoming less and less appropriate in this day and age. A data center that delivers digital value, calculates demonstrably efficiently, reports transparently and makes its residual heat part of a local energy solution is of a different order.

So we don't just need to build more efficient data centers. We mainly have to design chain-like solutions. Just as the LED replaced the incandescent lamp, the data center must evolve from an energy consumer to an integrated energy and data node. This requires transparency, measurability and cooperation between IT, energy, real estate, government and heat consumers. Only then will it become clear how much value we really get from each kilowatt hour.