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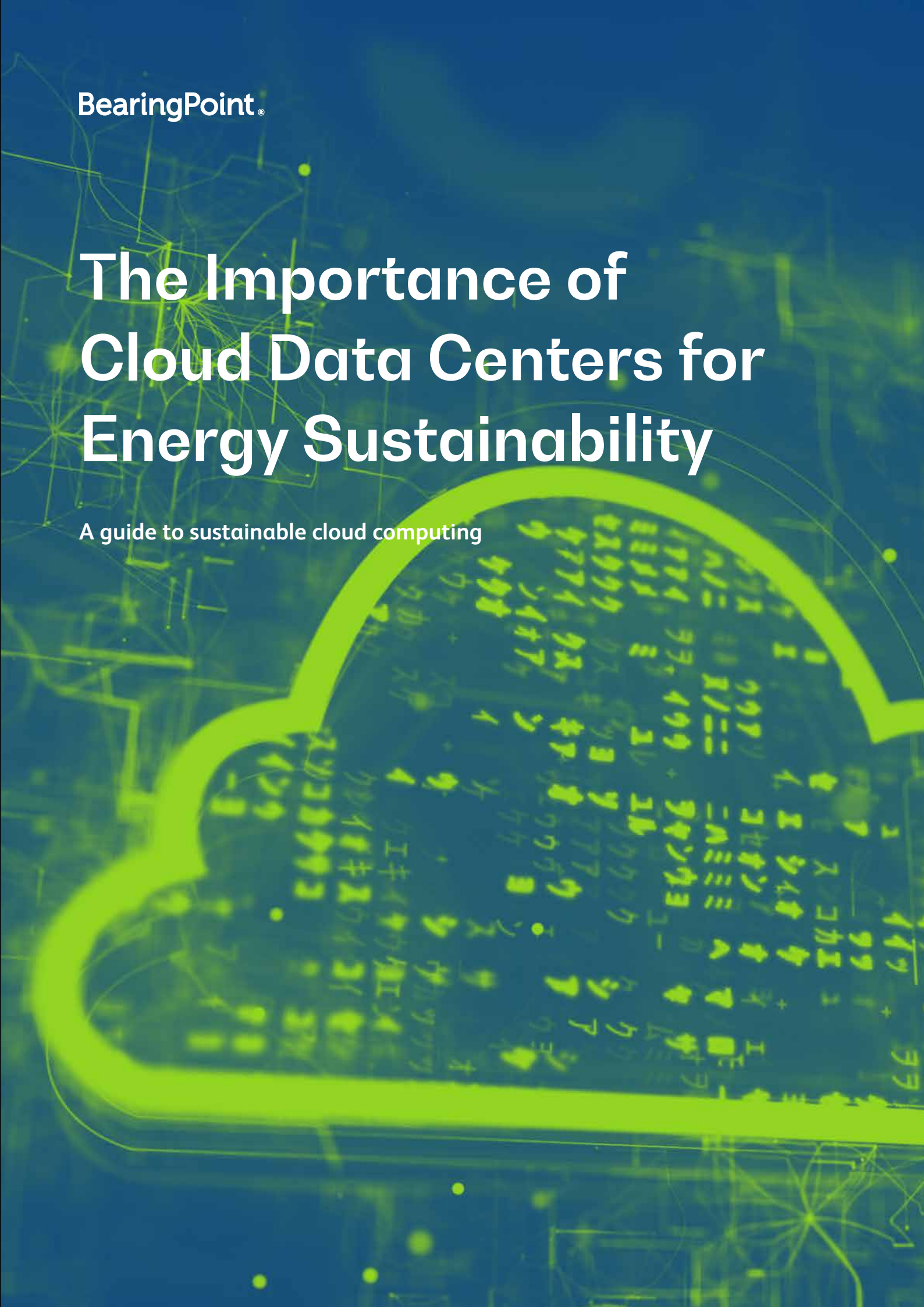
The Importance of Cloud Data Centers for Energy Sustainability

A guide to sustainable cloud computing



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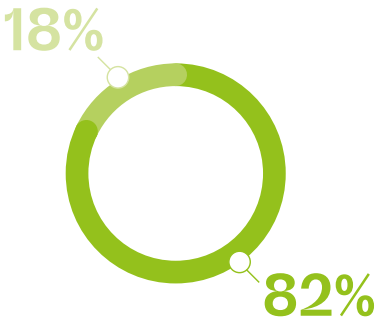
Cloud solutions clear the way to net-zero emissions

With 16 TWh[1] of demand in 2020, data centers are among the biggest energy consumers in the information and communications technology (ICT) sector. Being such a high energy-consuming factor, cloud solutions could make an important contribution to reducing the overall environmental impact. The Deutsche Energie Agentur GmbH (dena) stated that there is an energy savings potential of 87 percent[2] when office applications are moved to the cloud.



A Bitkom Cloud Monitoring suvery from 2021 shows that 82% of German companies with 20 or more employees are already using cloud infrastructures.

That makes an increase of 17% since 2016.

Footnote: 3

It is justified for companies to move to cloud computing for security reasons, cost savings, and scalability, but they could also benefit from a smaller ecological footprint. With companies being held accountable in the fight against global warming, cloud providers are also going green. In a 2020 study, 80 percent[4] of consumers viewed sustainability as the most important issue when evaluating businesses. In addition, companies must reduce emissions and work toward carbon neutrality to align with today's sustainability regulations.

With the new government in Germany came new regulations and climate measures in a digitalization plan that will also impact data centers – the German government wants data centers to be climate neutral by 2027. Public data centers will also need certification, such as Blue Angel, that will be transparent to customers.

So how can businesses tackle the transformation toward green cloud computing?

"Green Cloud Computing" resulted from a joint project by the Fraunhofer IMZ, the Öko-Institut and Agentur tipping points GmbH. The life cycle based data study looked at resource requirements such as raw materials used and cooling systems to answer questions about the environmental impact of cloud services ("How much energy does a gigabyte of online storage consume?"). The study, commissioned by the German Federal Environment Agency, calculates the environmental impact of cloud services to deliver a common base for comparing different services and online and offline solutions. The overall picture shows that cloud computing can positively affect future products, markets and business models using economies of scale.

An introduction to green cloud computing

Green cloud computing combines cloud computing with the goal of reducing its impact on the environment. It is used to describe an environmentally friendly cloud. Scalability, security and cost-effectiveness make cloud computing essential for today's businesses. Sustainability can also be a significant driver of cloud computing.

The Federal Office for Information Security follows the National Institute of Standards and Technology (NIST) in defining cloud computing as "a model for enabling convenient, on-demand network access to a shared pool of configurable computer resources (such as networks, servers, storage systems, applications and services) that can be provisioned rapidly and released with minimum management effort or service provider interaction."

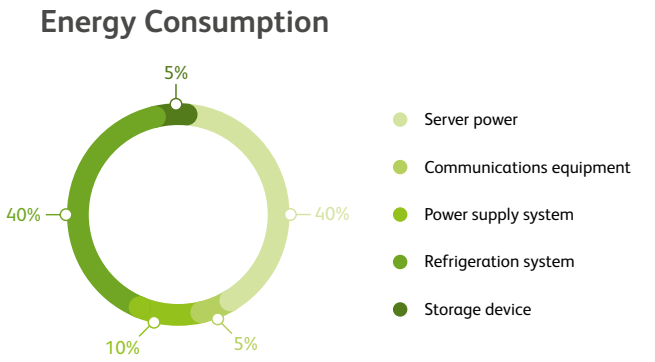
1 Hintemann (2020)
2 Engelhardt et al. (2017)
3 Weber (2017)
4 Cheung et al. (2020)

Sustainable cloud computing must consider the whole lifecycle, from design and production to usage. Multiple drivers add to sustainability, in particular, more efficient utilization. Shared data centers use the advantage of scalability to add and remove resources based on the short-term alternating demand of companies. The more Software as a Service (SaaS) models in place, the lower the requirements of end-user devices – energy-saving processors become sufficient. Software and network optimization can be highlighted as the main techniques to reduce the overall power consumption of cloud systems.

Here are some goals that drive the process of green cloud computing:

1. **Reduction of resources**
   Resources should be environmentally and resource-friendly throughout their lifecycles while aiming for high-capacity utilization. For cloud data centers, that means the considerate handling of natural resources, IT equipment and physical infrastructure-supporting equipment. The most significant resource consumption factors are cooling systems and IT equipment. Monitoring devices are one way to track and optimize the overall consumption during production, operation and disposal.

2. **Reduction of energy consumption**
   A sustainable data center needs to focus on the most significant energy consumption factors like server and communications equipment energy consumption, the power supply system, storage devices and cooling to reduce its energy consumption. With Power Purchase Agreements (PPA), a long-term contract on renewable energy resources, a cloud provider can ensure they are purchasing green energy. When reducing the number of active servers, for example, by implementing scheduling optimization methods and the number of running memory nodes, the consumed energy can be significantly reduced. Another energy-consuming factor is the communication between virtual machines. By reducing the network traffic between servers, energy consumption can be lowered.



Footnote: 5

3. **Reduction of carbon footprint**
   Using renewable energy in cloud data centers and building a more energy-efficient infrastructure can reduce carbon emissions. Allocating resources so that machines are only powered on when needed is much more energy-efficient and gives greater workload flexibility and better server utilization rates. Operators can also create clean energy transitions based on geographical analysis and data insights. Operating data centers remotely means data centers can be at locations where less cooling is needed and benefit from adjustments to the heating, ventilation and air conditioning system (HVAC).

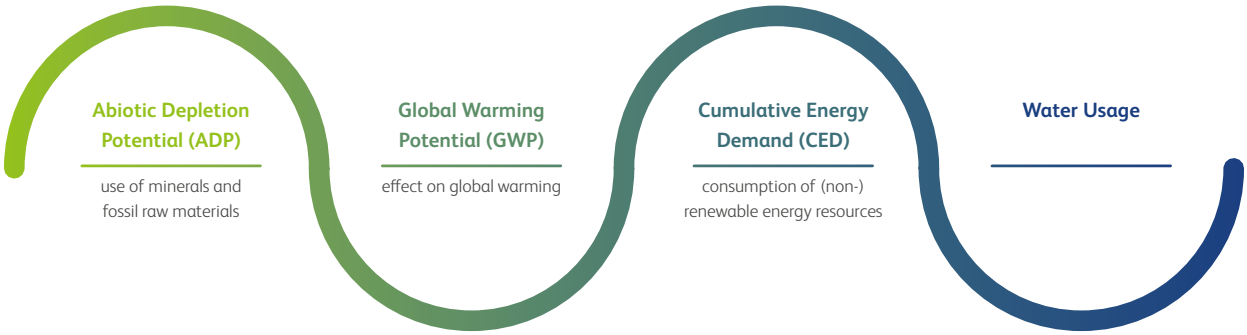
[5] Masdari, Mohammed et al. (2020)

Quantifying the environmental impact – an energy consumption analysis

How can the environmental impact of cloud computing systems be measured? A methodology published in June 2021 by the German Federal Environment Agency (UBA), called "Green Cloud Computing" (GCC), proposes a calculation for the environmental impact based on impact categories. The GCC impact categories are embedded in the Key Performance Indicator for Data Center Efficiency (KPI4DCE), which resulted from a former study of the UBA.

The KPI4DCE had formerly replaced the widely used Power Usage Effectiveness (PUE[6]) and Data Center Infrastructure Efficiency (DCiE[7]) metrics. These were used in energy consumption analyses by calculating the load delivered to all computing hardware resources as IT equipment power and energy consumption by other facilities as the total facility power.

The GCC, however, describes effort indicators that can be calculated for cloud services. They are used to record the environmental effort for the production of IT technology and the operation of data centers based on four impact categories:



The environmental effort is then compared to the quantitative benefit. This quantitative benefit designates a service unit of a cloud service to which the effort can be assigned. This allocation is necessary because data centers usually offer different services with different hardware requirements simultaneously and are thus responsible for different shares of resource consumption. The benefit of the cloud service is expressed by a physical unit, such as greenhouse gas emissions in kilograms of carbon dioxide equivalent for virtual desktop infrastructure per virtualized workstation. IT is measured over the timeframe of one year.

Establishing an appropriate benchmark for the benefit against which to calculate the effort can be challenging. Dividing cloud computing models into the different services IaaS, PaaS and SaaS and using subareas such as server, storage, network and infrastructure can help with this challenge. The $\text{GCC effort indicator} = \frac{\text{effort}}{\text{benefit}}$ shows the effort required to provide a service. The lower the effort indicator is, the more environmentally friendly the service is. The GCC indicators are of great use when it comes to identifying potential for improvement from within a data center and communicating performance as an external view for customers.

[6] PUE is used for benchmarking a data center's energy efficiency. It indicates the ratio of the annual energy demand of the entire data center to the annual energy demand of the data center's IT: PUE = Total Facility Power/IT Equipment Power. Grance, Timothy; Mell, Peter (2011)

[7] DCiE = 1/PUE = (IT Equipment Power/Total Facility Power) x 100%. Grance, Timothy; Mell, Peter (2011)

Example from the “Green Cloud Computing” methodology: The energy expenditure of virtual desktop infrastructure

Balancing the energy consumption and CO_2 emissions generated by the virtual desktop infrastructure (VDI):

- The subject of the assessment are two data centers of a federal authority with approximately 1,000 employees at two different locations
- Example of services offered by the data centers: web server, database, mail server, print server, mobile device management, etc.
- $\frac{1}{10}$ of the data center capacity is used for VDI for 890 workstations

The energy consumption and hardware inventory of the two data centers is measured for 1 year	The annual resource consumption of a federal authority is determined according to KPI4DCE key figures	Allocation of hardware and other resources to VDI services	Annual resource consumption of the data centers for the respective cloud services is related to individual service units (VDI workstations)	Comparison with desktop workstations

Results

- For each workstation of virtual desktop infrastructure in the data center there are used:
  - Raw materials amounting to 0.22 grams of antimony equivalents (GCC VDIADP)
  - Greenhouse gas emissions of 59 kilograms of carbon dioxide equivalents (GCC VDIGWP)
  - Primary energy amounting to 995 megajoules (GCC VDICED)
- Of the hardware components, the server component makes the most considerable contribution to these three parameters.
- In terms of raw material requirements (ADP), the server accounts for 79 percent, while in terms of global warming potential (GWP) and cumulative energy expenditure (CED), it is 74 percent in each case.
- The resource expenditure for the provision of the VDI workstation is significantly influenced by the number of hardware resources used for the VDI and the efficiency of the infrastructure services.
- The resource expenditure for the VDI workstation can differ depending on whether the data center resources are used for the VDI according to demand or are oversized.

A path to a green cloud – a customer perspective

Businesses have little motivation to use cloud solutions. Or do they? Government regulations and the environmental awareness of customers are driving businesses to rethink their branding and carbon emissions. For both consumers and providers, there are ways to go green when it comes to cloud computing.

Provider perspective

1. **Green coding/sustainable software engineering**
   Efficient algorithms and optimized software programming are the way ahead for cloud providers. A clean-IT initiative of the HPI suggests:
   - Using efficient patterns and considerately choosing between polling and event-driven background operations

Consumer perspective

1. **Select a carbon-thoughtful provider**
   Choosing a transparent cloud provider with the means to measure and manage the carbon emissions for data electricity consumption, manufacturing and disposal can be a decisive step. Making workloads more visible and tracking progress gives quantitative clues on saving energy. Carbon footprint metrics can be applied

- Decoupling software components to support up and downscaling by switching, for example, between monolith, microservice and serverless architectures
- Implementing metrics for more insights in the code, e.g., KPIs for resource consumption
- Using fast data structures and libraries with better algorithms
- Using non-functional requirements like performance to raise the bar for lower resource consumption and higher energy-efficiency

2. **Effective server utilization (virtualization)**
Virtualization technologies can contribute to sustainable ICT practices by hosting multiple applications through one server. When dividing one server into multiple virtual servers, so-called virtual machines, storage space, RAM and processor power can be allocated precisely to the total available capacities. The number of active servers is reduced, and the overall energy consumption is lowered. Using a shared server can save energy by 80 percent[8] Besides higher server availability, virtualization helps lower operating costs, raises application performance and reduces server complexity. The type of virtualization depends on whether a public, private or hybrid cloud is in place.

to improve the visibility of the company's footprint. Meanwhile, ESMA provides guidelines on outsourcing to cloud service providers based on capabilities, infrastructure, economic situation, and corporate and regulatory status. And there are even more factors to consider. Is the cloud operator using suggested measurements like from the "Green Cloud Computing" study that would help find precise solutions to reach net-zero emissions? Cloud data centers with fiber-based access also have smaller carbon footprints. Compared to copper and other transmission link elements, fiber optics have up to 12 times lower energy consumption. It also strongly reduces electromagnetic radiation and is more environmentally friendly to manufacture than other network types.

2. **Sustainable return on investment (SROI)**
When it comes to the ROI of Cloud Computing, it is necessary to put sustainability aspects into the equation and to factor them into the decision when calculating the cost-benefit of moving to the cloud. SROI is used to include environmental, social and economic aspects when estimating the financial outcome of business investments. When calculating the TCO, it also becomes clear where the costs for the in-house infrastructure are incurred and where there is potential for migration.

Cloud solutions move us forward in many ways

Companies can stop tons of carbon emissions from being released into the atmosphere with cloud migrations. Cloud services and cloud data centers have the potential to become more and more energy-efficient. Cloud solutions will become indispensable as costs are optimized and data security improves. Cloud services beat onsite IT infrastructures hands down in terms of emissions, which will lead to a higher customer satisfaction rate. And cloud solutions also help companies stay one step ahead, so that they keep prepared for future regulations.

[8] Ohri, Ajay (2020)

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