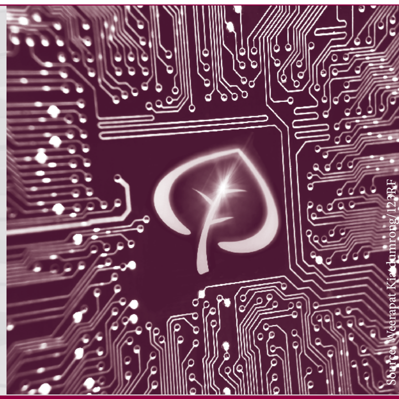
TAB OFFICE OF TECHNOLOGY ASSESSMENT AT THE GERMAN BUNDESTAG

Energy consumption of ICT infrastructure



Source: Weerapat Kiatdumrong/123RF

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Summary

- Due to omnipresent digitisation, the energy consumption of information and communication technology (ICT), i.e. of digital end devices, data centres and telecommunications networks, is becoming more and more important.
- Between 2015 and 2020, the annual energy demand of data centres and transmission grids in Germany increased by around 5.4 TWh. This corresponds to an increase of 30 %.
- Existing efficiency and saving potentials must be consistently tapped in order to slow down the current growth in consumption.
- In the TAB report, blockchain applications, private internet use and smart energy management in buildings have been examined in depth.

What is involved

Digitisation permeates all areas of life and involves considerable upheavals. So far, in science and the general public, the resulting enormous opportunities and risks have been addressed primarily in economic and societal terms. However, digitisation is also accompanied by considerable ecological impacts, which are considered to be ambivalent: On the one hand, digitisation offers the opportunity to reorganise economic and social processes and – in particular – to make them more efficient with regard to energy and resources. On the other hand, the establishment and operation of digital infrastructures (digital end devices, data centres, telecommunication networks) consume large amounts of energy and resources. A critical consideration of the energy consumption of ICT infrastructures is of considerable relevance, because – in view of the enormous potential benefits associated with digitisation – there is a certain danger that the negative environmental impacts involved might increasingly slip out of the focus of users, researchers and, last but not least, political decision makers.

Forecasts on the global energy demand of ICT infrastructures are inconsistent

Studies predicting a drastic increase in the energy demand of ICT infrastructures have caused quite a stir among the public. Some authors have predicted a tenfold increase or more by 2030 (in relation to 2010). However, these results are usually based on very simplifying assumptions. In contrast, other studies have concluded that the global ICT-related energy demand will not increase significantly in the future. This is often justified by the fact that considerable energy efficiency potentials can be tapped at many levels.

The energy demand of ICT infrastructures in Germany is currently increasing

For the TAB report, the electricity demand of ICT infrastructures (data centres and telecommunications networks) in Germany was determined based on sales figures, technical data on electricity consumption and use patterns of ICT components. The results for the reference year 2020 are as follows:

- The electricity consumption of data centres amounted to around 16 TWh/a. Compared to 2015, this corresponds to an increase of about 34 %. This increase is largely driven by the current trend towards ever larger data centres, even though these are usually operated in a comparatively energy-efficient way.
- The electricity demand of the telecommunications networks (fixed-line, mobile communications and broadband cable

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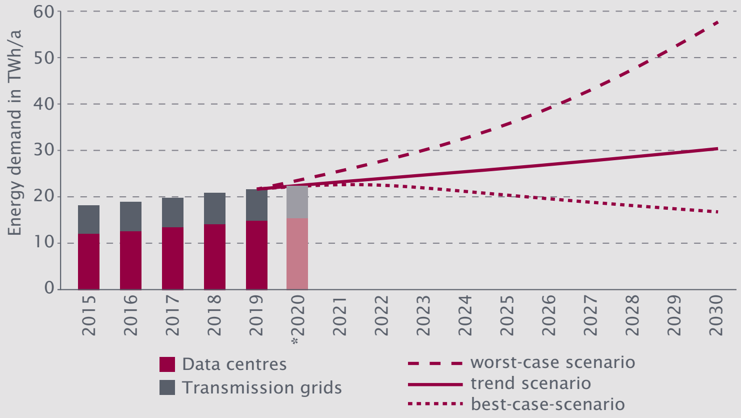
network) amounted to about 7.3 TWh/a. The increase compared to 2015 amounts to around 22 %.
- When ICT services are used in Germany, not only domestic resources are required, but – due to the pronounced international networking of the digital sector – considerable energy demands are also induced by ICT infrastructures abroad. An estimate showed that this share corresponds to at least 10 % of the energy demand of all data centres in Germany.

Nevertheless, in the past it has been possible to keep the increase in energy consumption within limits in relation to the rapid growth in the ICT sector. Responsible for this is the enormous progress made in microelectronics, which has led to a doubling of the performance of computer components about every two years, without their power requirements increasing to the same extent. Moreover, the energy efficiency of data centres could be increased by means of building technology (cooling systems, power supply, etc.) and organisational measures.

Abb. Scenarios regarding the energy demand of ICT infrastructures in Germany by 2030



* Update based on the state of knowledge of May 2022

Illustration by TAB based on Borderstep Institut (2019): Energiebedarf der IKT-Infrastruktur: Stand, Trends und Einsparpotenziale. (Fichter, K.; Hintemann, R.; Clausen, J.; Beucker, S.; Schramm, S.) Berlin; Borderstep Institut (2022): Aktualisierung und Ergänzung der TAB-Studie »Energieverbrauch der IT-Infrastruktur«. (Hintemann, R.; Beucker, S.; Schramm, S.; Fichter, K.) Berlin

Energy consumption by 2030: stabilised or tripled?

The future energy demand of ICT infrastructures in Germany significantly depends on the further development of energy efficiency. Possible development paths have been modelled using three scenarios (Fig.):

- The trend scenario continues the currently observed efficiency advances and increases in data volume. Under these conditions, the energy demand increases to 30.6 TWh/a in 2030.
- The worst-case scenario describes the development that energy efficiency can no longer be increased as much in the future as in the past. In this scenario, an increase in energy demand to 58.5 TWh/a is conceivable by 2030.
- In contrast, if the efficiency potentials were consistently exploited (best-case scenario), stabilisation and a slight reduction in energy demand would be possible in the long term compared to today.

The scenarios were based on the state of knowledge before 2020. The COVID 19 pandemic has led to an increased demand for cloud services and a significant increase in data traffic in mobile and fixed-line networks. From today's perspective, a significantly stronger increase in energy demand

Promising options for energy saving

In the project, five promising options for energy saving have been analysed in depth. These options are technologies or innovations that have a high energy-saving potential but are not yet widespread. Moreover, there are also effective ways of taking action for German stakeholders to influence the further development and application of these options.

Using waste heat from data centres

In German data centres, around 15 TWh of electricity is converted into waste heat every year, which has been cooled away largely unused so far. If this amount of heat would be used to heat buildings, several million tons of CO_2 could be saved per year. The lack of economic viability in the past and the fact that data centres are often not built in close proximity to heat consumers were identified as significant barriers to a more widespread use. Consequently, funding opportunities exist primarily in the form of targeted incentives, e. g. by means of municipal heat planning that links the location of data centres to the existence of heat consumers.

Liquid-cooled servers and systems

Today, data centres are usually air-cooled. Since liquids (e. g. water) are much better heat transfer media, liquid cooling is not only more efficient, but also considerably more energy-efficient. In addition, the waste heat accumulates at higher temperatures, which is advantageous for its further use (e. g. in local heating networks). However, there are reservations among operators as they consider the use of water to be a potential business risk due to the danger of short circuits. The initiation and promotion of demonstration plants as best-practice examples could help to break down these reservations.

DC power supply for data centres

Before the alternating current from the public grid is consumed in the ICT components of a data centre, it is converted to 39.2 TWh/a by 2030 is expected for the trend scenario. The assumptions for the worst-case scenario still seem plausible – while the best-case scenario no longer seems realistic. Stabilising energy demand at the 2020 level would already be a success.

Thus, in order to slow down the increase in energy demand of ICT infrastructures, existing energy efficiency potentials must be consistently exploited. For this reason, the TAB project identified more than 60 technological and organisational options for saving energy in ICT infrastructures and selected five of them for a detailed analysis (see box).

In order to obtain a more detailed overview of energy consumptions and savings opportunities, three fields of application from the ICT sector were also analysed in more detail.

Blockchain aplications: enormous energy consumption – unless countermeasures are taken

A blockchain is a tamper-resistant register, e.g. of transactions, that is stored in a decentralised way on many computers. The best-known practical application is the field of cryptocurrencies, which are, however, criticised due to their sometimes enormous electricity demand. The cryptocurrency Bitcoin alone is expected to have reached an electricity demand like that of Hungary (41 TWh/a) or Austria (66 TWh/a) in 2019. This is due to the underlying validation mechanism, according to which the execution of transactions requires a considerable calculation effort.

Though, there are alternative concepts to secure transactions in a much more energy-efficient way. Within the Bitcoin network, however, there are currently no plans for a change. Since external intervention in a blockchain is not possible, the main options left for policymakers are to regulate trading in energy-intensive cryptocurrencies in order to make them less attractive to users. However, it should be borne in mind that regional measures might not achieve the desired effect due to the distinctly global nature of cryptocurrencies.

From the experience gained here, it is important to learn the right lessons for public or state-backed blockchain applications in other fields (energy, transport, health, etc.). Here, it should be ensured right from the beginning that energy-efficient processes are used.

Private use of digital media and the Internet: drivers for the increase in ICT-related energy demand

The ICT-related energy demand of the private use of digital media and the Internet is made up of the energy consumption of the end devices (i.a. TV sets, PCs, routers) as well as the energy consumption in data centres and transmission networks induced by this. In addition, the manufacturing of devices also contributes to energy consumption. Under plausible assumptions, the manufacturing of smartphones or laptops, for example, requires around ten times the energy needed for using the device.

Overall, the operation of digital end devices in private households consumed as much energy as all data centres in Germany (15.1 TWh in 2018). In 2018, another 10.6 TWh/a was required in the transmission grids as well as in data centres in Germany and abroad. The COVID-19 pandemic has led to a significant increase in daily media use time and energy consumption – especially during periods of contact restrictions. However, this might have been a temporary effect.

several times into direct current and back again (at the input of the storage batteries for the uninterruptible power supply, at the transition to the house grid, at the power supply units of the ICT components). If the components were supplied directly with direct current from the batteries, these conversion steps and the energy losses involved could be avoided. However, DC components are only available in limited quantities and operators avoid the effort associated with the changes involved. In Germany, potential pilot users could be, for example, large state-backed data centres from the research or university sector.

Data centres as providers of balancing power

Data centres offer good technical prerequisites for providing the balancing power required for stable power grid operation thanks to the uninterruptible power supply systems (storage batteries and emergency power generators). Although this does not result in any electricity savings in the ICT infrastructures, covering the demand for balancing power without recourse to large fossil-fuel power plants can support the transformation of the electricity system. Possible options for action range from funding pilot and demonstration projects to obliging operators to provide grid services.

Renewable energies for ICT infrastructures

For ICT infrastructure operators, the use of renewable energy sources is an attractive option to reduce the ecological footprint of the ICT sector. However, a 24/7 full supply with volatile wind or solar power is difficult. Start-ups are currently developing innovative concepts, such as e.g. data centres that are built into the towers of wind power plants or software-based »swarm platforms« that shift computing loads to where electricity from renewable energy sources is available. However, there is still a lot of development and testing work to be done before technological solutions and business models can emerge from such approaches..

A look at the overall development of consumption shows a mixed picture: While the energy consumption of end devices has been tending to decrease since 2010 – mainly due to efficiency improvements – it is continuously increasing in the data centres and transmission networks. This is considered to be mainly due to the increasing networking of end devices and the increased private use of Internet services in general (particularly audio and video streaming).

Political efforts for energy savings in end devices should aim at maintaining and continuing the achievements regarding energy efficiency made so far. This would be possible e. g. by an expansion of consumption labelling through EU energy labels or the tightening of eco-design regulations. The growing consumption in ICT infrastructures can be slowed down by throttling the increase of the data volume processed. In this context, software development is a key factor. Here, more attention should be paid to the criteria of data economy and energy efficiency of applications. As the energy consumption of ICT infrastructure is hardly perceived by users, initiatives should be developed to raise consumer awareness of the issue and provide users with guidance for making appropriate decisions regarding their media and Internet use.

Smart Buildings: significant energy savings through the use of ICT in buildings

In order to investigate how the use of ICT applications enables energy savings in other economic sectors, the case study of using smart energy management systems for the heating supply of buildings was chosen.

It is difficult to precisely quantify the saving potentials, as they depend on the technical systems used and – to a large extent – on the individual users and their decisions. Assuming that the dissemination of smart energy management systems is pushed forward intensively, the saving potential by 2030 can be roughly estimated to be around 10 % of the amount of heat consumed in the building sector today.

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Thus, smart energy management systems can make an important contribution to the energy transition in the building sector that can be implemented relatively quickly compared to structural measures. The current enormous price increases for fossil fuels are further boosting the urgency of taking efficiency measures for existing buildings.

Conclusion

A further increase in the energy demand of ICT infrastructures can only be prevented if existing efficiency potentials are consistently exploited. First and foremost, it is the operators who are called upon to put innovative energy-saving solutions into practice. State actors have various possibilities to accelerate the diffusion of innovative solutions: Funding research, acting as a pilot user, using the leverage of public procurement, raising awareness of the issue among users and, last but not least, regulation and the dismantling of regulations that hinder innovation.

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