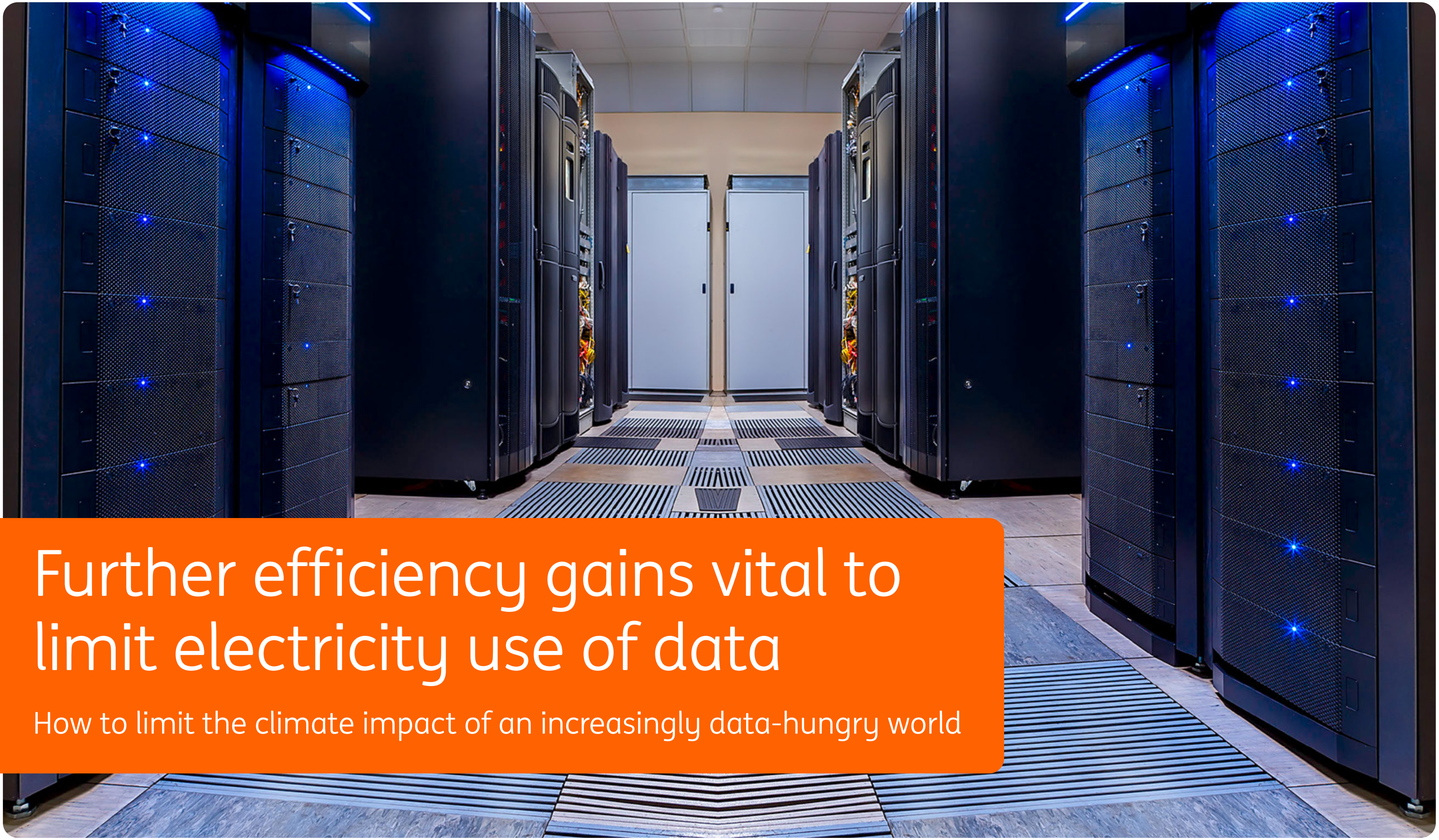


Further efficiency gains vital to limit electricity use of data

How to limit the climate impact of an increasingly data-hungry world

ING Economics Department • November 2019

ING

Introduction

Preface

Amounts of data at unimaginable levels

Billions of people watching videos on their smartphone, more and more machines connecting to the internet, blockchain calculations being performed and many companies moving their businesses into the cloud.

The data behind these activities travels over networks, through the air, and via underground and submarine cables that pass through ever expanding data centres. The technology sector is increasingly considered to be an electricity guzzler of interest. It is often assumed that the amount of data will skyrocket in the coming decade, which will also lead to increasing energy consumption. With energy reduction – in relation to climate impact – becoming a top priority for businesses and governments after the Paris agreement, this aspect is of increasing interest to the technology sector. Electricity use is relevant for tech companies such as cloud providers, software vendors, data centres, internet service providers and mobile network operators. Their data-related electricity use is determined by both data volumes and efficiency.

This report focuses on the energy needed to enable data to flow and will therefore investigate:

- To what extent data flows will increase and what this means for electricity consumption;
- What impact additional electricity consumption has on achieving the Paris climate goals; and
- What technology companies can do to limit energy use.

Contents

Conclusion

Data growth will be staggering

By 2030, global dataflows are expected to be more than 20 times those of 2018. This staggering growth is driven by more people having access to the internet, more internet traffic per user, connected machines, cloud services flourishing and more big data and computations in AI.

Share of data-driven electricity use will probably increase from 3% to at least 5% of global use...

The exponential growth in data means power use for these flows will double and therefore grow to about 5% of worldwide electricity use in 2030. Networks and data centres in particular will see the strongest growth.

...without efficiency gains this share will be more than 30%

Increasing data demand means network and data centre services require more and more power. Without efficiency gains the share of data in global power use would rise to more than 30%. To keep the rise in electricity use limited to 5% of global power use, electricity use by network and data centre services has to get substantially more efficient. Recent history shows that the efficiency improvement needed can be achieved, but it requires power-saving innovations to continue.

Focus on efficiency to limit climate impact of data

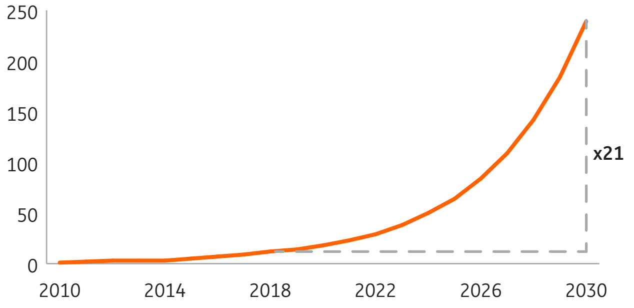
Devices, networks and data centres handle large quantities of data. In limiting the impact that growing data flows have on CO_2 emissions, the tech and telco (telecoms) sector should focus on implementing efficiency-increasing innovations that limit electricity use.

Sourcing renewables to limit climate impact of growing electricity use

A strong rise in electricity use seems inevitable, given the huge growth in data. Therefore, in addition to focusing on implementing efficiency-increasing innovations, using renewable power to generate electricity is vital to further limit carbon emissions. Focusing on creating additional renewable energy capacity can prevent a potential shortfall between required and available green power.

Cloud data increases twentyfold towards 2030

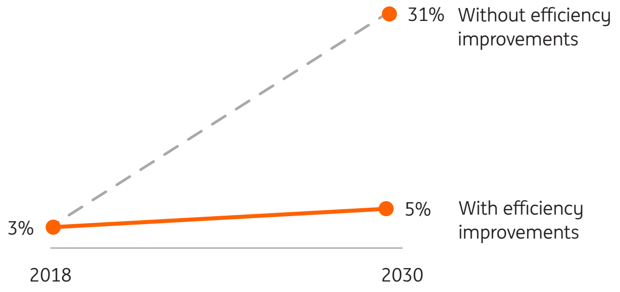
Total data flow per year in ZB



Source: ING Economics Department based on Cisco

Around 5% of global power needed for data flows

Electricity use as % of total electricity consumption worldwide



Source: ING Economics Department based on BNEF

Future potential average annual efficiency gains seem attainable from a historical perspective

	Efficiency gains (CAGR) 2010-2018	2018-2030	Efficiency drivers in future
Devices	4%	3%	• Shift towards handheld • Low energy design
Networks	17%	15%	• Shift away from 2G and 3G • 5G power management, architecture and protocols
Data Centres	25%	16%	• Scale: larger share for efficient hyperscalers • AI energy management

Source: ING Economics Department calculations

1 | Devices are currently the main power users

Devices, networks and data centers determine electricity use for data flows

This report looks at total power use for data flows by taking the following as components:

1. **Devices**
2. **Networks**
3. **Data centres**

Currently, over 40% of electricity is consumed by devices, with networks responsible for about a third and data centres (DCs) for a quarter.

More detailed description

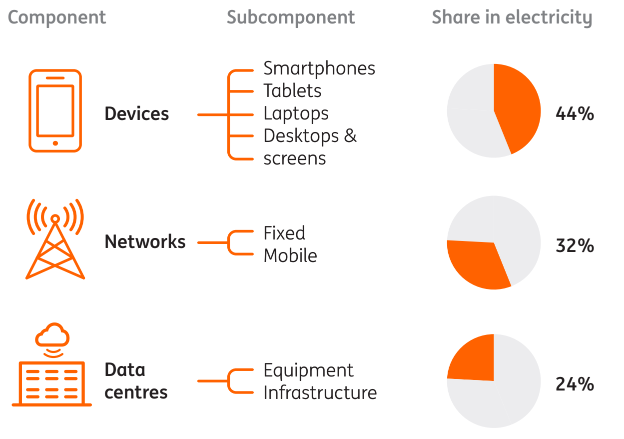
To provide more insight into what makes up the three components of data-related electricity use, the table below presents a more detailed description of devices, networks and DCs.

Devices, networks and data centres determine electricity use for data flows

	Definition	What part of electricity use is in scope
Devices	Computers, tablets, smartphones and other mobile phones of businesses and consumers generating, sending and receiving data.	• During use ('at the plug'), not manufacturing and disposal. • Electricity use of other connected devices out of scope because their primary role is not communication or data storage (e.g. connected washing machine, car).
Networks	Mobile and fixed-line networks used to transfer data, operated by telecoms players and other carriers.	• Electricity use of equipment such as switches and routers, transmission link elements and supporting infrastructure for cooling, power, etc. • Traditional fixed telephony is excluded.
Data Centres	Providers of storage, processing and distribution of data	• Power for the IT hardware (e.g. servers, storage drives and network devices) as well as the supporting infrastructure (e.g. cooling, lighting). Consists of single tenant (private), multi-tenant (co-location) and hyperscale data centres.

Currently devices consume more than 40% of electricity for global data traffic

Electricity consumption per year as a percentage of total, 2018



Source: ING Economics Department based on BNEF, IEA

2 | Electricity intensity and volume determine power use

Power use depends on both the amount of data and intensity

Electricity use in this report is determined by both volumes and how efficient devices, networks and data centres are. This is the electricity intensity, or the power needed per unit.

Power use of devices is the number of devices in use times the electricity use per device. Networks' total electricity use is network data times electricity use per byte. For DCs, this is cloud data times the electricity intensity, in this case electricity per byte of data.[1]

On the next page, we look at how device numbers, data flows and the electricity intensity and subsequent electricity use have developed in the past.

How are software companies involved in power use?

Although the software sector is not at first sight a driver of electricity use, it has a role in:

- Software efficiency: Software-related electricity use by **devices, networks and DCs,** such as the efficiency of the operating system and applications both through coding (programming language), design (e.g. background) and other attributes.
- Software defined: Using software to shape generic hardware into different functions for **networks** and **DCs**, which also has an impact on power use.
- Software managed: Automatic upscaling and downscaling of **network** and **DC** IT infrastructure, enabling an increase or decrease in hardware capacity.

How is eletricity use of devices, networks and data centres determined?

		Number of ...		Electricity intensity measured as...
Electricity use of devices depends on	=	Devices	X	Electricity use per device
Electricity use of networks depends on	=	Bytes of network data	X	Electricity use per byte
Electricity use of data centres depends on	=	Bytes of cloud data	X	Electricity use per byte

1 Drivers of electricity use are more complex in reality, especially for DCs. DCs use power for storage, communication and computation function through the servers the DC houses (expressed in MWs).

3 | Electricity rise was limited despite sharp data increase

Data flows show strong increase...

The amount of data and number of devices has grown in recent years. Especially data has shown strong growth:

- More and more people and their devices are constantly online;
- More and more data is generated and collected; and
- Businesses are moving their activities online, into the cloud.

All this requires a constant movement of data. Therefore total cloud data volume reached 11.6 zettabytes[2] in 2018, – a tenfold increase on 2010. Network data flows, mainly internet data, were more than eight times the levels in 2010.

...while electricity use only goes up 1.2 times...

To enable these data flows, electricity is needed to run the hardware and the software that transports data across the globe. It is estimated that more than 800 TWh is consumed yearly, about the power use of Belgium, the Netherlands and Germany combined. Between 2010 and 2018, the power needed increased by 23%, or by approximately 1.2 times that of 2010, despite the gigantic data increase.

...meaning electricity intensity declined

This means that the electricity intensity of data flows has decreased, requiring substantially less electricity per zettabyte of data. Potential explanations of this development are more efficient semiconductors[3] plus advances in transmission technology and compression technology.

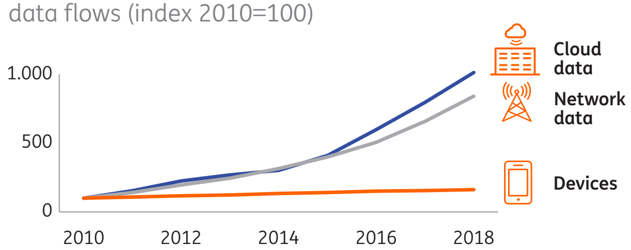
Tech sector limits power use despite data growth

The share of the technology and telco sector in total global electricity use is fairly stable at around 3%. So, despite the enormous increase in data flows, the sector has succeeded in limiting the rise in electricity demand by becoming more energy-efficient.

The question is whether the sector can continue to keep its share in electricity use stable in the future, given an expected data increase. It will require substantial improvements in electricity intensity through further technological advancements. In looking towards the future, this report takes 2030 as the horizon.

As the pace of data growth keeps increasing...

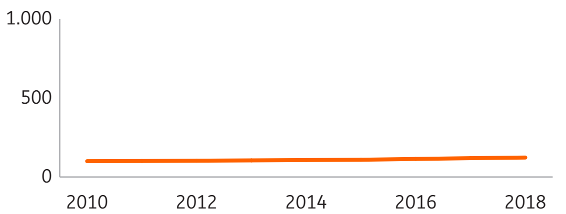
Development of number of devices, network and cloud data flows (index 2010=100)



Source: ING Economics Department analysis based on Cisco VNI, GSMA, Andrae

...the rise in power used is limited...

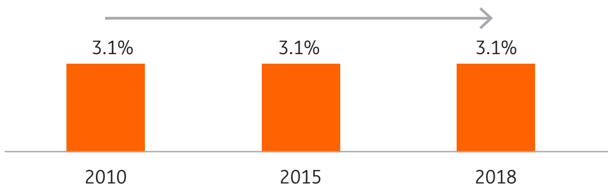
Development of electricity used for data flows (index 2010=100)



Source: ING Economics Department analysis based on IEA and others

...therefore the share in power needed remains stable

Electricity for data flows as % of total electricity consumption worldwide



Source: ING Economics Department calculations

2 A Zettabyte is a 1 followed by 21 zero's, with bytes being the unit of digital information

3 How much electricity a computer consumes (at peak-output) is subject to Moore's law, the observation that the number of transistors that can be crammed onto a chip of a given size doubles every two years.

4 | Networks and data centres became much more efficient

Electricity intensity in more detail

Overall, the tech and telco sector managed to considerably reduce electricity intensity in the past few years. In this case, we will look at how electricity intensity developed for devices, networks and data centres specifically, and what significance it holds for limiting power use.

Data centres use less electricity than networks per byte of data

Currently electricity consumed per zettabyte of data for DCs is almost 90% lower than for networks. Electricity intensity of devices is at 27 TWh per billion devices.

Data centres and networks show biggest increase in efficiency

Between 2010 and 2018, devices have increased in efficiency by 4% yearly on average, benefiting from a focus on battery life improvement (display, processor). Both networks and DCs have significantly improved their electricity intensity (CAGR of 17% and 25% respectively). Fixed networks have benefited from the move to fibre cables, which require less energy than copper and greatly benefit from advances in transmission technologies. Mobile networks have increased efficiency with every generation.
Data centres have seen the application of infrastructure management technologies and improvements in cooling that also allow a higher standard temperature. Furthermore, equipment has seen improved utilisation and has become more electricity-efficient

Electricity intensity: a lever to pull

Electricity intensity is the key to limiting the tech and telco sector's future electricity consumption. The main question therefore is: how can energy intensity be improved?
And what effort is needed to limit additional electricity consumption?

The following pages will describe future devices and data growth and then focus on innovations and trends that contribute to further improvements in electricity intensity of devices, networks and data centres.

Electricity intensity decreased significantly between 2010 and 2018

	Average annual improvement in electricity intensity 2010-2018 (CAGR)	Main efficiency drivers
Devices	4%	• Display technology • Solid state drive or SSD (flash memory) • Improvements to battery technology • Processing efficiency (Moore's Law)
Networks	17%	• Moving from copper to fibre • Multiplexing; combining multiple signals and transporting these over a single fibre • Network virtualisation
Data Centres	25%	**Equipment:** • Virtualisation • Scaling • Processing efficiency (Moore's Law) • SSD **Infrastructure:** • Higher temperatures • Hot/cold air separation • Free air cooling

Source: ING Economics Department

5 | Future data growth dwarfs further increase of devices

We will look at future developments for devices, networks and DCs, and zoom in on their drivers: the number of devices, network data and cloud data.

Devices

Number of devices shows weakening growth

Growth in the number of devices (computers, tablets, smartphones and other mobile phones) in use will be limited to 1.7% on average towards 2030.[4] This growth is mainly determined by:

- **Population growth** of 1% yearly towards 2030.[5]
- The potential for growth in **the number of devices per capita** is limited, translating into an additional annual increase in devices of 0.7%. Most of the developed world has already reached saturation levels. In developing countries, there will mainly be a substitution of ordinary mobile phones with internet connected smartphones.

Networks

Data over networks doubles in size every 2 to 3 years

Global IP traffic over networks will continue to grow at a strong pace, roughly doubling in size every 2 to 3 years. Network data growth is mainly driven by the following:

- The **number of people having access to the internet** in Asia, Africa and South America is growing.
- A strong increase in **internet traffic per user** is expected, partly due to video and gaming, supported by faster broadband speeds
- More **machines will be connected to the internet** (internet of things [IoT]) generating, sending and receiving data.

Data centers

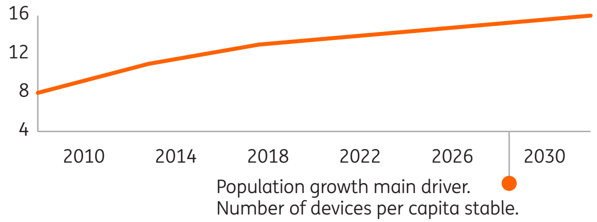
Cloud data will continue to see exponential growth

Global cloud data will see strong growth, doubling approximately every 3 years. Cloud data flows will grow mainly due to:

- **DC-to-DC traffic** increasing as cloud services flourish, data is moved between clouds and replicated across DCs. CDNs (content distribution networks) gain importance as streaming media grows.
- **Within-DC traffic** growing. Big data and AI computations are significant drivers of traffic within the DC. More data is generated, collected, exchanged, analysed and stored.
- **DC-to-user traffic** expands. As this part largely overlaps with network data (which in addition includes peer-to-peer data), its drivers are the same.

Growth in devices limited

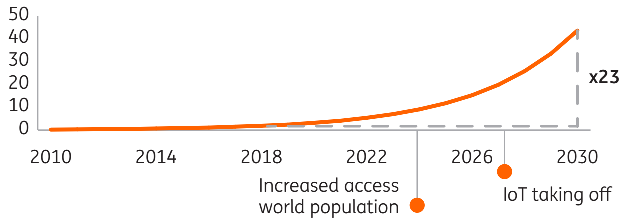
Total number of devices in use in billions



Source: ING Economics Department based on GSMA, Andrae

Network data 23 times bigger in 2030 than in 2018

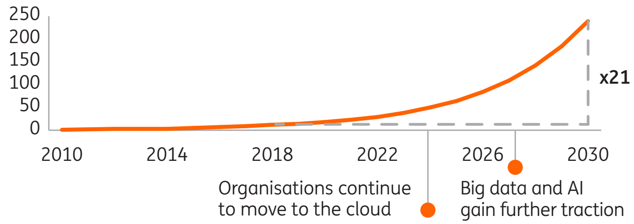
Total data flow per year in ZB



Source: ING Economics Department based on Cisco

Cloud data increases twentyfold towards 2030

Total data flow per year in ZB



Source: ING Economics Department based on Cisco

4 Note that the IoT will result in more machines connecting to the internet, but these are not in scope under devices. Their primary role is not communication or data storage, and most of their energy consumption is related to their primary role.

5 UN World Population Prospects 2019 estimate.

6 | Devices: Shift to handheld devices drives down future power use

With the ongoing strong growth in data in mind, the focus will have to be on electricity intensity to limit future electricity use. The following three pages will look at what data growth will mean for power use with and without further efficiency gains. It will also describe efficiency drivers.

Slow growth in numbers and shift towards handheld devices keep electricity use in check

As it stands, 1.4% of worldwide power is used by devices. Without innovations, electricity use would only go up at roughly the same pace as global power use, as growth in the number of devices is restrained. As a result, devices would use 1.2% of total electricity in 2030.
Battery-powered devices are already highly energy-efficient. Overall, the average energy intensity of devices can improve further mainly because desktop computers lose ground to less energy-intensive devices (e.g. tablets).

Assumptions and forecasts 2018-2030

- The main driver of the improvement in electricity intensity is the shift towards **less energy-intense** devices. By 2030, 86% of devices are handheld (2018: 71%), resulting in efficiency improvement of approx. 3% per year.
- Low-energy design innovations are estimated to result in an additional **decrease** in energy intensity of approx. 0.5%

Low-energy design main route to further increase efficiency

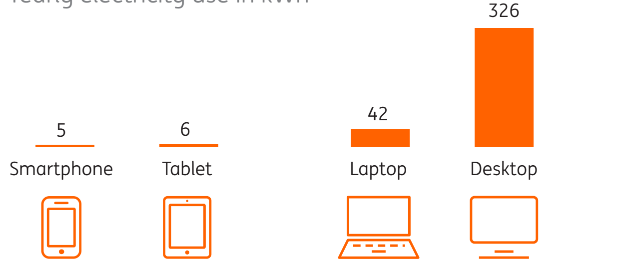
Processors and screens use the bulk of electricity in devices. Semiconductor manufacturers remain focused on low-energy design, bringing chips to market that can perform the same tasks as before while using less electricity. In practice, this means better performance while roughly keeping electricity use the same. The main innovations to drive electricity efficiency in processors are:

- **Intelligent, dynamic power management:** Finishing a job quickly and efficiently to enable a faster return to the ultra-low-power idle state.
- **Power efficient design:** Improvements to circuit design and component integration, e.g. power gating (reducing power by turning off parts of a design) or multi-supply voltage techniques (using different voltages for different chip parts).
- **Heterogeneous computing:** Combining central processing units and special purpose accelerators such as graphic processing units on the same chip saves energy by eliminating connections between discrete chips.

The efficiency improvements can lead to an estimated 3% annual decline in electricity intensity. That drives electricity use down to 0.8% of worldwide power use.

Smartphone and tablet use much less power than computers

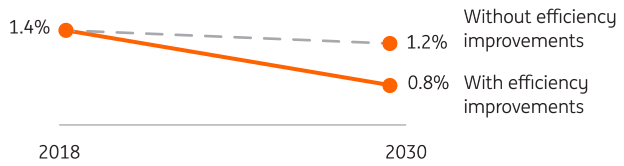
Yearly electricity use in kWh



Source: Fraunhofer USA

Improved power intensity leads to a drop in relative power use by devices

Electricity use as % of total electricity consumption worldwide



Source: ING Economics Department calculations, BNEF

7 | Networks: swift drop in 5G energy intensity needed to prevent power demand surging

Impact of going mobile softened by generational shift

Networks currently use 1% of total global electricity. In the absence of efficiency changes, this would grow to almost 18% in 2030. However, consumers and businesses use more and more mobile devices and data. This would drive up electricity use even further, as mobile networks are more electricity-intense than fixed lines. However, mobile networks have become significantly more energy-efficient with every generation. As network carriers invest more heavily in mobile networks, the phaseout of energy-intensive legacy networks accelerates.

Assumptions and forecasts 2018-2030

- Shift towards wireless and mobile networks results in 3-5% **increase** in electricity intensity.
- Shift from 2G and 3G towards 4G and later 5G networks means approx. 10% **decrease** in electricity intensity.
- Other changes (e.g. move to fibre, intensity of equipment such as switches, and reducing AC-to-DC conversion losses) result in 8-10% **decrease** in electricity intensity.

Designing and improving 5G networks with energy efficiency in mind is crucial.

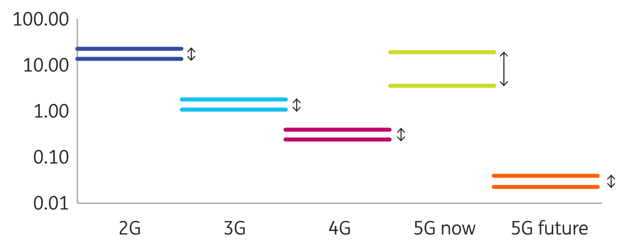
The next generation networks, 5G, are rolled out in the coming years. 5G technology is based on high frequency, shorter wavelength signals that can carry large amounts of data – but not nearly as far as current systems. This means investing in much more equipment and antennas. The main concern therefore is that the increased speed of 5G (up to 20 times faster than 4G) will require a denser tower infrastructure and, consequently, require more electricity. To overcome this, energy efficiency can be improved by:

- **Power management** for base stations (switching off when idle). This becomes more relevant as data can be transferred in a shorter time, creating longer periods in which the network connection can be idle.
- New **5G architecture** leads to better infrastructure scaling, lower computational redundancy and fewer hardware systems, reducing overall energy consumption. Software-defined networking enables a quick roll-out of energy efficiency enhancements.
- New **protocols** (e.g. on compression) and techniques (e.g. beamforming, directing radio transmission signals in a specific direction) reduce power consumption.

Innovations and shifts between networks will probably lead to an estimated aggregate energy intensity improvement of 15% annually. This results in a rise towards 2.5% of worldwide power being used for networks in 2030.

Mobile network energy intensity declines with every generation

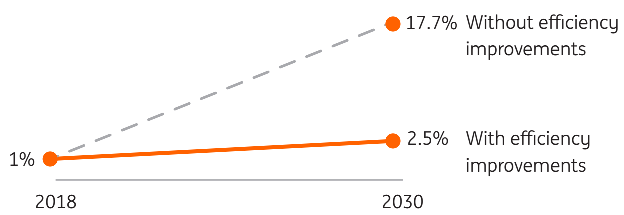
Electricity intensity range (kWh/ GB) of network transmission by access type



Source: IEA, ING Economics Department. Please note the log scale

Networks' share in power use moves towards 2.5% after efficiency gains

Electricity use with and without efficiency increase as % of total electricity consumption worldwide



Source: ING Economics Department calculations, BNEF

8 | Data centres: Scaling and AI to boost energy efficiency

The average size of DCs continues to increase

At the moment DCs use about 1% of worldwide power. Without further reduction of electricity intensity, data growth would lead DCs to use 12% of global power by 2030. Supported by the move to the public cloud, hyperscale DCs continue to increase their share in total DC capacity. This reduces the proportion of private, small-scale less efficient DCs and improves overall electricity efficiency.

Hyperscale: much more efficient

Hyperscale data centres – very efficient, large-scale cloud facilities – are very much focused on electricity use, not only for infrastructure (e.g. cooling) but also for IT equipment. They deploy specialised, more efficient servers and components, including through open source (e.g. Open Compute).

Abstraction to continue

Larger scale DCs make use of virtualisation and containerisation. Virtualisation allows multiple virtual machines (VM) to run isolated processes or applications on a single server, sharing the underlying resources and dramatically increasing the utilisation rate. However, it still requires running heavyweight operating systems (OS), which draws on RAM, CPU and storage. Containerisation technologies enable multiple VMs to use the same lightweight OS. This drives a further reduction of energy use.

AI expected to further boost energy management

DCs will increasingly deploy artificial intelligence (AI) to autonomously handle various tasks such as server optimisation and equipment monitoring. AI will assist in reducing energy consumption by controlling cooling equipment and collecting sensor data to detect and subsequently fix energy inefficiencies.[6] A next step is to use machine learning to optimise computer chips in servers.

Impact of edge computing on energy use unclear

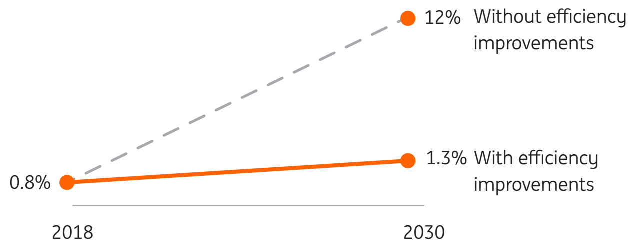
Edge computing is about processing or storing critical data locally with parts sent to central DCs. It's important for IoT, where machines produce but also process vast amounts of data. As the impact on overall energy use is not clear yet and IoT devices are not in scope, the impact of edge computing on electricity use is not taken into account here.

Altogether, innovations are estimated to lead to a yearly 16% improvement of electricity intensity. This means that, despite strong data growth, the rise in the relative power used by DCs will be limited, consuming 1.3% of worldwide power in 2030.

6 Google's Deep Mind project realised a 40% gain in cooling energy consumption.

Efficiency gains at data centres mean rise in electricity use is restrained

Electricity use with and without efficiency increase as % of total electricity consumption worldwide



Source: ING Economics Department calculations, BNEF

Assumptions and forecasts 2018-2030

- The main driver of the improvement in electricity intensity is the shift towards large-scale, efficient DCs, with improved equipment, cooling efficiency, storage and utilisation. This shift leads to an approx. 20% **decrease** in electricity intensity early on, later slowing to around 10%.
- Energy management through AI contributes 5% per year to **decreasing** electricity intensity, starting in 2022.
- Other measures such as better UPS batteries, higher temperatures and reducing AC-to-DC conversion losses contribute 1% per year.

9 | In 2030, 5% of global power is needed for data flows

Data flows require 5% of global power in 2030

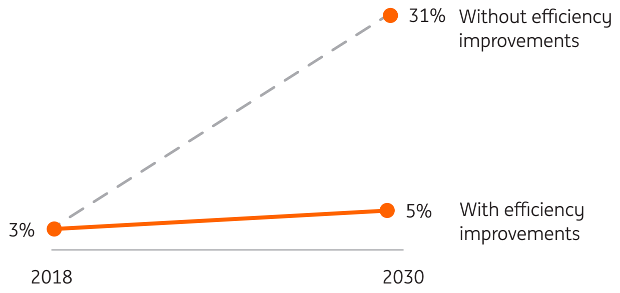
The electricity needed for dataflows by devices, networks and data centres doubles between 2018 and 2030 to approximately 1650 TWh. Over that period total worldwide power demand is expected to rise by about a third, which is for example due to electrification in transport and industry. This means by 2030 power demand by the tech and telco sector represents approximately 5% of worldwide electricity use.

Innovations substantially limit power use

The gains in efficiency substantially reduce the growth of electricity use due to increasing data flows. In light of historical efficiency gains, these expected efficiency improvements seem attainable.

Around 5% of global power needed for data flows

Electricity use as % of total electricity consumption worldwide



Source: ING Economics Department calculations, BNEF

Future potential average annual efficiency gains seem attainable from a historical perspective

	2010-2018	2018-2030
Devices	4%	3%
Networks	17%	15%
Data Centres	25%	16%

Source: ING Economics Department calculations

10 | Using renewable energy is key to limiting CO_2 emissions

Additional power need impacts climate goals

Signatories to the Paris climate agreement have committed themselves to reducing their CO_2 emissions. Electricity that is generated by fossil fuels is a major source of these carbon emissions. The expected rise in electricity needed for data flows will therefore make it harder to reach the Paris goals if the corresponding power is generated by fossil fuels. As a result, the impact of data growth on carbon emissions depends on how this power is generated. As DCs and networks will be the main drivers of power use for data in the future, we will focus on how power is sourced in that domain.

Grid mix determines CO_2 emissions

Power sourcing for DCs and networks can be split into:

1. production for self-consumption
2. electricity from the grid.

Production for self-consumption can be fossil-fuelled (e.g. diesel generators) or from renewable sources. In the case of DCs in particular, self-generation of renewable electricity is limited as power is needed 24/7. This is hard to attain with wind and solar power, and on-site generation using hydro and biomass only goes so far.

DCs and networks therefore predominantly rely on the grid, so CO_2 emissions are dependent on the power mix of the grid. The higher the share of renewables in this power mix, the lower the CO_2 emissions.

PPAs the most effective way to add renewable capacity

Current CO_2 emissions are determined by the current power mix. Companies can however stimulate the share of renewables in the future power mix. The most effective way to do this is to enter into a power purchase agreement (PPA). In a PPA, the user enters into a long-term contract and commits to purchasing a specific amount of renewable electricity at an agreed price. This provides power producers with certainty, so they will be more inclined to invest in additional renewable generation. This is particularly relevant in a subsidy-free environment in which investments in renewables are subject to market risk.

Certificates provide less incentive for extra renewables

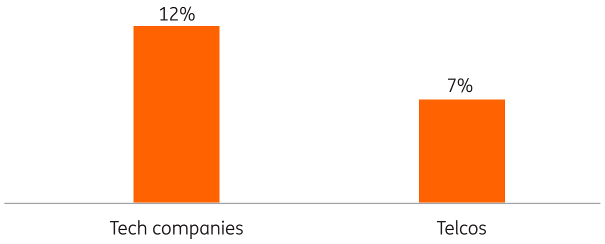
Unbundled energy attribute certificates, such as guarantees of origin, prove that a certain amount of electricity originates from a specific renewable source. These, however, trade at prices of typically €1 to €2 per MWh, providing limited incentive for creating additional renewables capacity.

Increasing renewables share requires additional capacity

The likes of Apple, SAP and Equinix have formulated 100% renewable electricity targets for all of their activities. IRENA figures show that – currently - 7% of all electricity used by telcos is renewable, over half of which in certificates. For corporates in the tech sector, renewables make up 12% of their total power consumption (59% in certificates). An increase in the share of renewables is therefore likely. The future challenge may then be how to fulfil the demand for renewable power. Preventing a potential shortfall will require a focus on investing in new solar and wind-powered facilities to increase capacity.

Renewables share of tech and telco sector limited

Share of renewable electricity in overall electricity use, 2017



Source: IRENA

11 | More can be achieved when combining power-saving innovations and renewables

Lowering electricity intensity: the crucial first step

For the tech and telco sector, contributing to the Paris climate goals will first and foremost require a decrease in networks' and data centres' electricity intensity. That responsibility for efficiency improvements is shared with suppliers and clients. Manufacturers for instance have to develop more efficient equipment before operators of networks and data centres and other clients can invest in it. Secondly, the sector can limit climate impact by using renewable electricity to enable the data flows. Some of the steps that specific players can take are listed below:

Steps different players can take to limit the climate impact of data

Players	Focus area	Steps
Data centre operators (hyperscalers, hosting, co-location, single tenant)	Efficiency	• Focus on efficiency of infrastructure technology, especially cooling • Monitor and improve efficiency of equipment (hyperscale, hosting) • Monitor and advise clients on efficiency of their equipment (co-location)
	Renewable energy	• Create new renewable power generation facilities through PPAs and self-generation. • Use excess heat for agricultural, industrial and residential purposes (excess heat offsets)
Network operators (MNOs, carriers, tower companies)	Efficiency	• Increase network efficiency through power management • Phasing out early-generation mobile networks
	Renewable energy	• Switching power for off-grid and bad-grid towers from oil generators to renewables
Software companies (Independent software vendors, ISVs)	Efficiency	• Measuring energy consumption of software: to identify software inefficiencies, improving software engineers' skills set and the evolution of the software product • At a strategic level: adding sustainability as a product characteristic, improving overall product quality and potentially increasing the success of the product
IT service providers (system integrators, managed services providers)	Efficiency	• Make electricity use/climate impact of solutions/decisions transparent to clients • Work with suppliers of equipment and services that are focused on limiting electricity use

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