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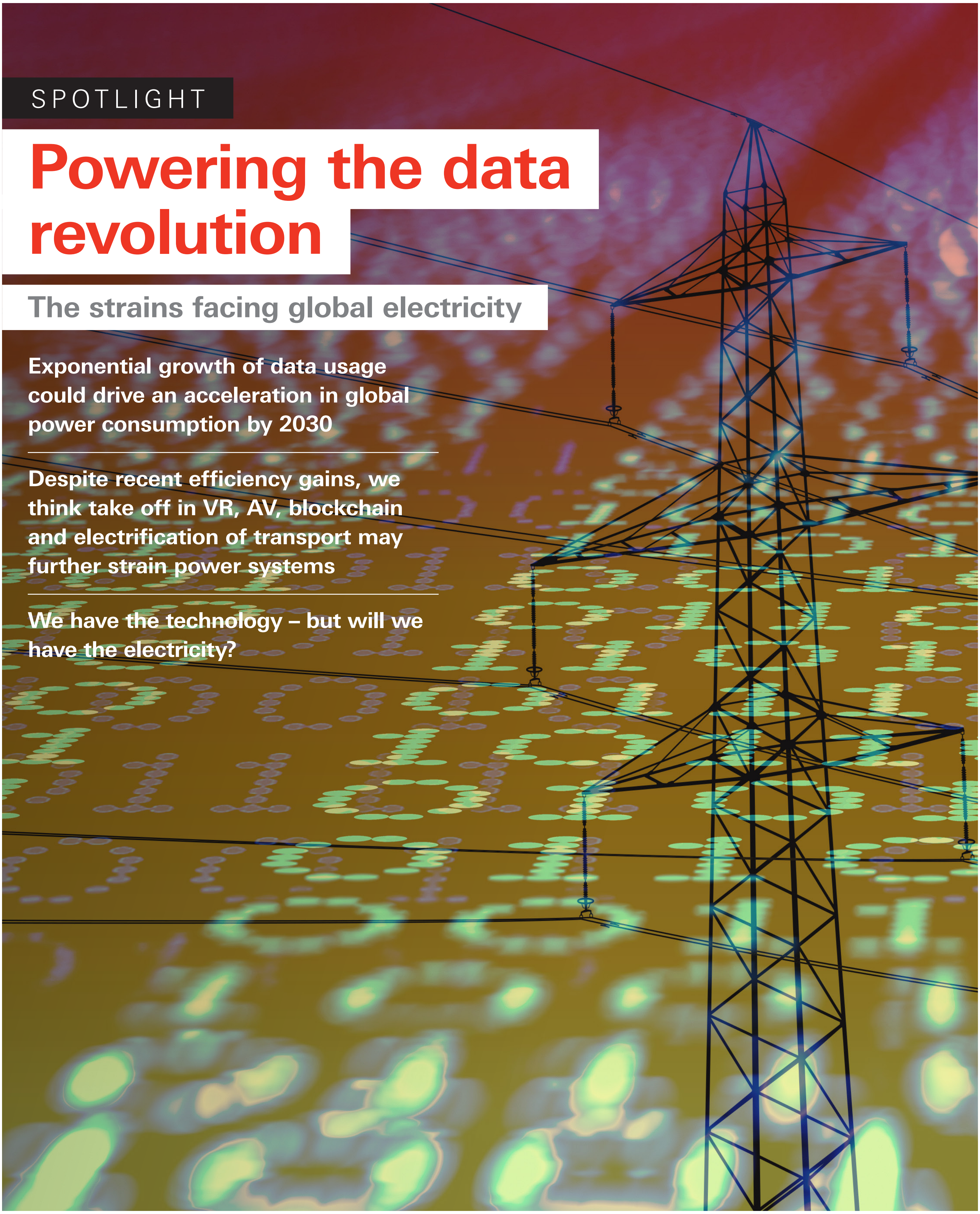


SPOTLIGHT

Powering the data revolution

The strains facing global electricity

Exponential growth of data usage could drive an acceleration in global power consumption by 2030

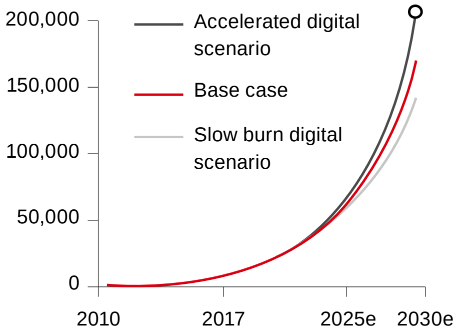
Despite recent efficiency gains, we think take off in VR, AV, blockchain and electrification of transport may further strain power systems

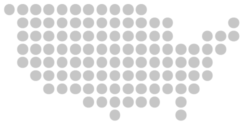
We have the technology – but will we have the electricity?

Powering the data revolution

Powering the data revolution will drive the acceleration of global energy consumption

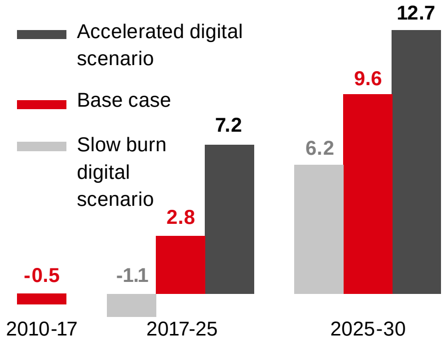
Global data centre IP traffic (Exabytes/year)





In our accelerated digital scenario we estimate that the data revolution will drive an **additional need of 2,300 TWh of power**. This is akin to **adding 60% of the power use** of the United States from 2017 to the year 2030

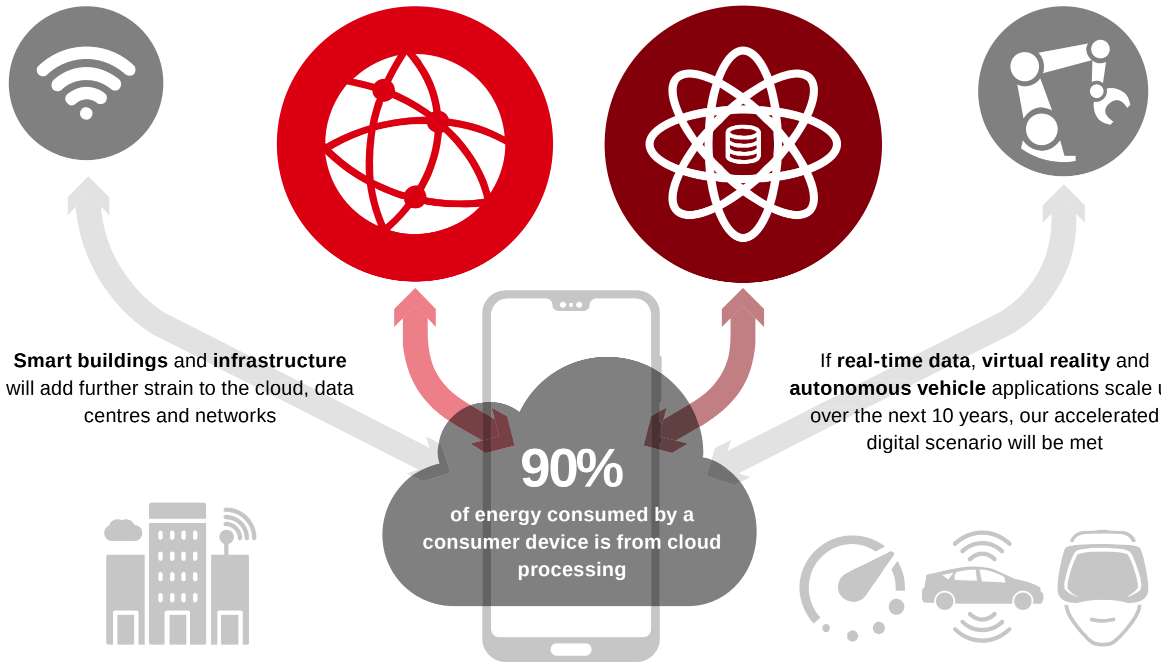
Projected global energy growth from digitisation (CAGR %)



Information and Communication Technology (ICT) could use between 8.6-19.3% of global electricity demand

Slow burn and accelerated digital scenarios: demand by sector by 2030

Consumer devices	Networks	Data centres	Production
PCs, mobile devices, home entertainment	Fixed wired, fixed wireless (Wi-Fi) and wireless (mobile)	Storage infrastructure	PCs, mobile devices, home entertainment, data centres, networks
1.7%-2.2%	1.6%-7.1%	4.2%-7.2%	1.1%-2.7%
3.8% (2017)	2.1% (2017)	1.3% (2017)	1.7% (2017)



Source: HSBC

Executive summary

- Digitisation will require twice as much electricity by 2030; in our base case, we forecast ICT related electricity consumption to double by 2030 to 3,900TWh
- Rapid adoption of EVs and take off in VR, AV or blockchain may take this total to 6,200TWh
- Rising power consumption may strain power grids and could slow the pace of the data revolution

The following is a redacted version of a report published on 30 May 2019. Please contact your HSBC representative or email Research.Direct@hsbc.com for more information on how to access the full report.

Powering our digital future

One hundred and fifty years after the commercialisation of electricity (led by Werner von Siemens, Sir Charles Wheatstone, Samuel Alfred Varley) and more than one hundred years after the war of currents, electricity is yet again changing the world we live in by powering the data revolution.

After a decade of exponential data growth, another one lies ahead

Digitisation is moving at speed. The pace of data consumption globally continues to accelerate, enabling a wave of new technologies over the next decade – the Industrial Internet of Things (IIoT), artificial intelligence (AI), autonomous vehicles (AV), virtual reality (VR) and blockchains like bitcoin (which is back at 12-month highs on renewed market interest)[1], to name but a few.

These technologies require huge data manipulation, made possible by increasingly sophisticated hardware, ever larger and more powerful data centres and the next generation of communication network infrastructure, 5G, which is arguably at the beginning of a tumultuous growth trajectory.

Over the next decade, the switch to private and commercial electric vehicles (EVs) will also gather pace, as will efforts to promote electric heating over gas heating. Yet, we believe the challenge of powering such a data revolution is underappreciated, and, in our view, the topic is under-researched.

We think the power consumption risks of growing data usage are underexplored

In this note, we analyse some of the fundamental assumptions underlying the widely held view that digitisation is part of the solution to the very problem it is creating, i.e. that digitisation will improve the flexibility and efficiency of power systems, that new generations of equipment will enable efficiency improvements in IT and communication networks to continue to keep pace with the world's rising thirst for data. After all, recent data shows that overall power consumption has not risen, despite higher data consumption.

We explore why this correlation may break down; in our base case, we see the potential for global power consumption to accelerate post 2025, with two key implications. First, without the necessary power infrastructure investments, grids may be less able to meet demand, introducing instability and security risks and potentially slowing the uptake of new data heavy applications. Second, unless incremental power generation is low carbon, we see potential risks to the pace of decarbonisation efforts.

Please contact your HSBC representative or email Research.Direct@hsbc.com for more information on how to access the full report.

[1] "Bitcoin rallies 10% to hit 12-month highs", The FT, 27 May 2019

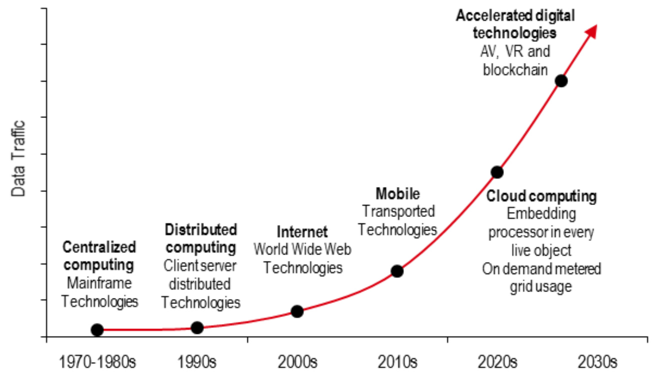
Powering the digitised world

- Power consumption of ICT could double by 2030, with a sharp acceleration post 2025…
- …if the current rate of efficiency improvement does not keep pace with demand growth
- We look at different scenarios and their implications

Digitisation feeds on electricity: Exabytes feed on terawatts

As society and industry become ever increasingly digitised and connected, we believe it's important to understand the relationship between this digital growth and the increasing demands on the global energy system. This has many implications, including economic and environmental, for emerging markets (EM) and the developed markets (DM), both at macro and company-specific levels. In this note, we argue that, more likely than not, we are underestimating the impact from the digitalisation of everything on the global energy system.

Chart 1. Key innovations driving growth of digitisation and data in society: an illustration



Source: HSBC

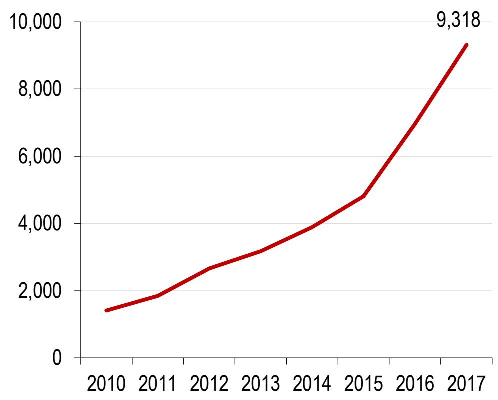
A decade of exponential data growth lies ahead

Digitisation continues to move at a rapid pace. This means that data consumption growth also rises globally, enabling a wave of new technologies in industry and society over the next decade – the Industrial Internet of Things (IIoT), artificial intelligence (AI), autonomous vehicle (AV), virtual reality (VR) and blockchains like bitcoin, to name but a few. Many of these innovations will drive the growth of real-time data processing applications and deliver almost instant updates to billions of devices, and thus will continue to drive the exponential growth in data consumption.

Powering all the data…

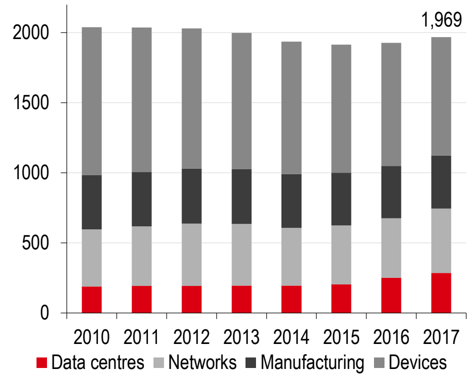
The total power requirement by Information and Communication Technology (ICT) has remained roughly stable at c2,000TWh, already a meaningful number that amounts to roughly 9% of global electricity consumption. The flat curve is largely the result of more power efficient devices, which have offset the rising demand from data centres. A look at the mix shows a shift towards data centres and data networks. The growth of cloud computing partly helps explain, in our view, the growth of global data centre IP (internet protocol) traffic from 2010 to 2017, which increased sevenfold (see chart 2) and the rising energy consumption of data centres (from 189TWh in 2010 to 284TWh by 2017) and the associated networks, which play a role in supporting data centres, which grew from 408TWh to 460TWh by 2017 (see chart 4).

Chart 2. Exponential growth of global data centre IP traffic (Exabytes/year)



Source: Cisco

Chart 3. Electricity usage (TWh) of ICT 2010-17 – efficiency offsets data consumption growth



Source: Cisco, HSBC estimates

But there are risks that efficiencies might not be able to keep up with growth of data

As new technologies take off, we believe global data centre IP traffic may balloon from 9,000 Exabytes/year (EB/year) in 2017 to 170,000 EB/year by 2030. The International Energy Agency (IEA) projects data centre power consumption to remain flat to 2021[2], driven by continued efficiency improvements, thanks largely to the ongoing move to cloud computing and more wide-scale adoption of power efficient data centres. Beyond 2021, we see power consumption from data centres rising dramatically (from 284TWh in 2017 to 1,699TWh in 2030), as well as in associated networks (from 460TWh in 2017 to 1,101TWh in 2030).

22TWh

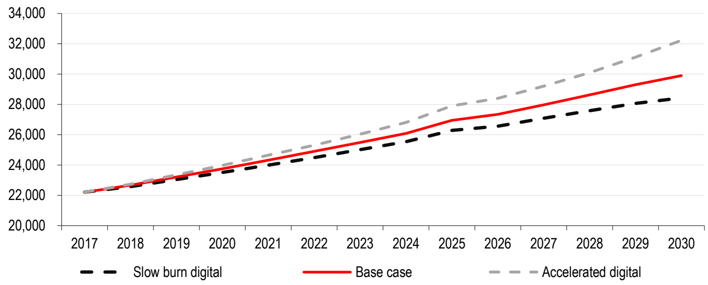
Power used for bitcoin mining in 2018, +600% y-o-y[3]

EM vs DM

Although analysis of power requirements of individual countries is out of the scope of this note, we can draw some general conclusions regionally. Driven by the data revolution, we estimate global power demand will increase by 2,300TWh by 2030 in an accelerated digital scenario (chart 4).

We suggest this may well potentially place additional strains on grid systems within EM compared to DM, partly given different power usage trends and less robust infrastructure and partly if there is a push for data centre localisation over the coming decade.

Chart 4. Power estimates to 2030 (TWh)



Source: HSBC estimates, IEA

Conversely, whereas DM electricity demands have remained broadly flat, this potential regionalisation of data centres in the future could also push DM electricity demand to increase by 2030, also driving grid concerns.

[2] "Data centres and data transmission networks", IEA, March 2019

[3] "Why bitcoin uses so much energy", The Economist, 9 July 2018

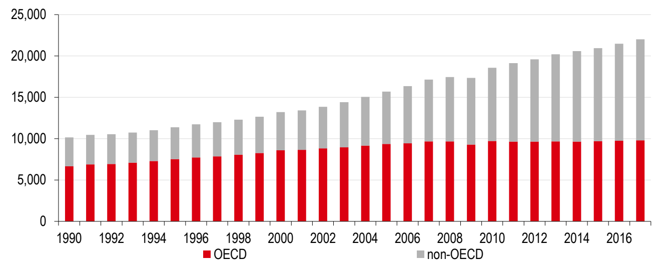
Global power overview

- Global power consumption grew 3% per annum from 2000 to 2017 fuelled by EM, where demand grew 7%
- Power consumption in the developed world grew by 1% over the same period, but demand has now been stable for a decade
- We see most pressure on EM grids over the next decade

Global power trends

The key takeaway of historical global electricity consumption trends is that developed world energy growth is lower than in the emerging market. Chart 5 highlights energy consumption growth in the OECD has more or less flat-lined since the early 2000s and non-OECD countries have continued to grow.

Chart 5. Non-OECD country power consumption growth is faster than OECD (TWh)



Source: IEA, WEO, BP Statistics

The primary drivers for the flat electricity demand in the developed world, despite economic growth, are continuous efficiency improvements and decreasing industrial activity as advanced nations like the US and in Europe outsource their low skilled manufacturing jobs, reducing their own power consumption.

Additionally, despite the increase in computing, home heating/cooling and lighting needs driven by population growth, per capita electricity usage in DM has declined due to strong efficiency improvements and technological upgrades. In contrast, electricity demand in EM has been growing at a steady rate, driven by the rising manufacturing sector, rapidly growing population and use of less efficient technologies.

Chart 6 shows power consumption growth by country from 2000 to 2017; here, we see that all of the top ten are from the emerging markets, with China at the helm with almost 10% growth. Nine of the lowest ten in terms of energy consumption growth are from the developed world, with the UK sitting at the bottom with a declining growth rate of -0.6%(!).

Chart 6. Power consumption growth breakdown by country 2000-2017, CAGR %

Country	Growth %	Country	Growth %	Country	Growth %
China	9.9	Chile	3.9	Czech Rep.	0.6
UAE	7.0	Mexico	3.5	Norway	0.6
India	6.8	Argentina	3.2	Netherlands	0.6
Algeria	6.7	Colombia	2.9	Venezuela	0.6
Indonesia	6.4	Brazil	2.8	South Africa	0.5
Nigeria	6.3	Taiwan	2.4	France	0.5
Saudi Arabia	6.1	Poland	1.8	Italy	0.4
Egypt	5.7	Australia	1.4	United States	0.3
Iran	5.6	Portugal	1.4	Germany	0.3
Turkey	5.5	Russia	1.3	Belgium	0.3
Kuwait	5.3	Spain	1.3	Japan	0.2
Malaysia	5.3	Uzbekistan	1.1	Ukraine	0.1
Kazakhstan	4.5	Romania	0.9	Sweden	0.0
Thailand	4.5	New Zealand	0.8	UK	-0.6
South Korea	4.3	Canada	0.8		

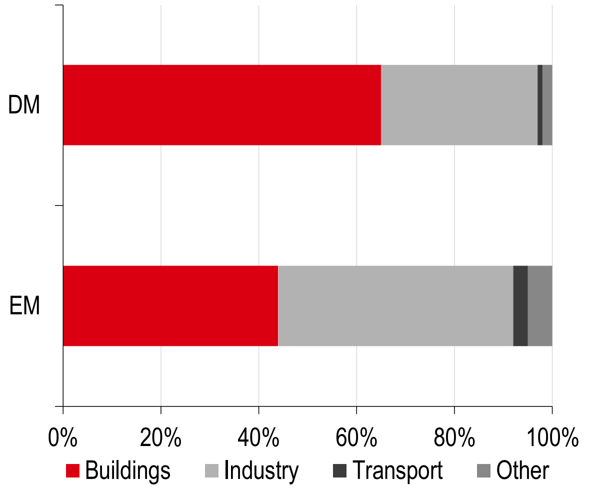
Source: Enerdata

Different power demands for developed and emerging markets

A look at EM and DM trends highlights some key differences. In DM, the percentage of power from buildings is 65%, with a large component of this from heating and appliances. Only 32% of total power comes from industry. This can be explained by generally colder climates in DM compared to EM and higher levels of electrification of households and businesses.

In EM, the largest component of power consumption is industry (48%), which reflects a greater share of GDP from primary and secondary economic activities as well as lower heating requirements and lower levels of electrification in households and businesses. Many EM countries still have underdeveloped electricity networks; according to the Rockefeller Foundation, an estimated 1.2bn of people globally in 2017 were living without access to electricity, mostly located in Africa, Asia and Latin America.

Chart 7. EM and DM show a different breakdown of electricity use (2017 data)



Source: IEA

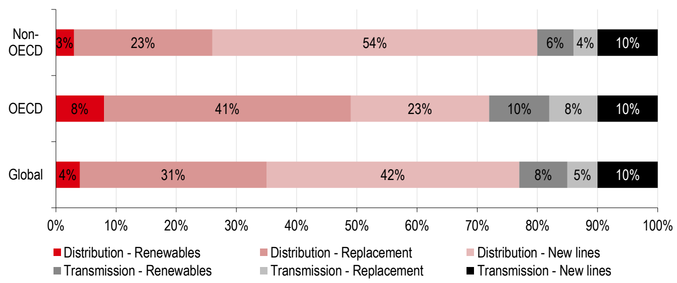
Which grids are best able to cope?

It is challenging to take a global view of how well electricity grids are placed to cope with rising power demand from digitisation. A broad-brush look at the breakdown of global Transmission & Distribution (T&D) spending split by OECD and non-OECD suggests that, in EM, investments are more focused on new lines (to extend existing infrastructure and connect new users), whereas in DM they are more geared to replacement lines and integration of renewables (given already high penetration and higher electrification levels is households and businesses).

DM grids have on average a higher penetration rate of variable renewables in the power mix and higher levels of electrification of households and businesses. Greater focus in DM grids should thus be on 'smartening' ageing grid infrastructure so that it is able to cope with higher power peaks and greater variability of power resulting from a higher proportion of renewables.

EM grids have, in general, a less well developed structure and lower penetration of variable renewables. The focus in EM grids should more likely be centred on ensuring robustness to meet higher GDP-driven demand and future-proofing new infrastructure to prepare for a lower carbon (and more renewables heavy) build-out over the next decades. We would thus argue that EM grids are broadly more at risk than DM grids of not coping with incremental take-up of digitalisation trends, leading to rising power demand growth.

Chart 8. Global T&D investment (2015 data) shows EM focus on new lines and DM focus on replacement and renewables integration



Source: IEA

EV charging power needs

- We see EV charging driving 300TWh of power needs per year by 2030, and likely rising rapidly beyond 2030
- Wider EV penetration requires the parallel build-out of charging infrastructure
- Public EV charging points represent a potential USD50bn investment opportunity to 2030 across China, US and EU

EVs driving build-out of electric charging infrastructure

The wider uptake of EVs faces an infrastructure challenge, which in our view should not be underestimated. Public charging infrastructure needs to be properly incentivised and regulated in order to stimulate the necessary investment. Failure to build enough publically available charging points could ultimately slow the uptake of EVs over the next decade.

The vast majority of buyers of EVs to date are not only enthusiastic consumers willing to pay a premium to own an EV, but also able to install a privately owned residential charging point to recharge the EV when parked at home. Yet broadening the penetration of EVs into cities and into lower income segments will require a wider build-out of public charging infrastructure.

'Charge anxiety' follows closely behind 'range anxiety' in terms of consumer concerns. A 2016 McKinsey consumer survey of customers in China, Germany and the US considering buying a battery electric vehicles (BEV) named the key barriers to uptake as:

1) Price
2) Driving range
3) Not having enough access to public charging stations.

Technology improvements and greater competition among auto original equipment manufacturers (OEMs) should help to address the first two barriers. The third barrier can only be overcome through the build-out of public infrastructure.

Longer-term mass electrification of transport therefore requires the build-out of publicly available charge points on commercial and industrial (C&I) sites.

According to the IEA, 117k publicly accessible electric car chargers were installed globally in 2017, 10% fewer than in 2016, at a total cost of around USD3bn. This brings the total number of publicly accessible charging stations to 430k, of which 25% are fast chargers. Half of these charging points are in China.

50%

Of fast chargers worldwide are in China

McKinsey concludes that the industry may need to invest up to USD50bn in public charging infrastructure through 2030 in the EU, US and China, of which 30% is in public charging infrastructure in C&I locations.

According to Aurora Energy Research, EV charging in the UK represents a cGBP2bn investment opportunity by 2040 (to enable c17m EVs) and in Germany over EUR3bn (to enable 23m EVs by 2040).

Can power grids cope?

The rapid growth of EVs is unlikely to tip the scales for global power demand but risks increasing peak demand far beyond the level that existing power systems can generate.

Even with 120m EVs on the road, the total charging requirement is only 1% of global power consumption by 2030 (assuming 2% compound annual growth rate (CAGR) of the 2017 global consumption total of 22,000TWh).

So, although risks to overall power supply are low, the impact of a surge of EVs plugging in to charge during the evening hours risks creating localised pressure points on electricity distribution grids.

Smart can address the issue

We think it is important that smart charging models emerge, potentially capping the connected capacity of EVs needing to recharge and rewarding consumers for delaying charging.

Future power scenarios

- We challenge the assumption that power efficiency gains will keep pace with data consumption growth
- We model digitalisation growth and create three energy scenarios: slow burn digital, base case and accelerated digital
- Please contact your HSBC representative or email Research.Direct@hsbc.com for more information on our three scenarios

We might be underestimating the power needed for the data revolution…

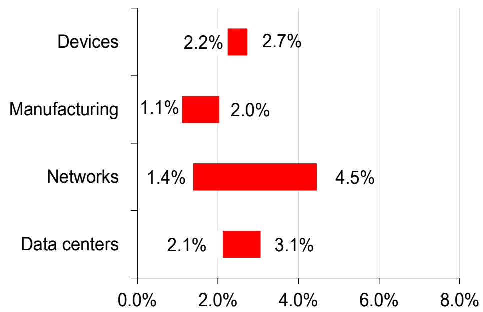
The IEA estimates data centres will only use about 1% of global electricity by 2021 and estimates similar numbers for networks. As the IEA itself suggests, these forecasts are based on a highly optimal scenario in which energy efficiencies keep materialising. Current global electricity forecasts from the IEA and other institutes therefore are based on such assumptions.

Currently, forecasts from the IEA and World Economic Outlook (WEO) see 29,900TWh of electricity consumption by 2030. According to these forecasts, global power demand is expected to grow at a CAGR 2.4% from 2017-2025 and then slow to 2.1% during 2025-2030.

Between 2017 and 2019, the IEA lowered its estimate for global data centre electricity consumption from 3% to 1% for 2021, citing improved power efficiency of data centres. It thus appears that institutions like the IEA are considering continued energy efficiencies in the data revolution as the basis of their estimates to 2030. Yet we see reasons to believe that future estimates for 2030 may not have the same efficiency assumptions for digitisation.

As technology frameworks such as Koomey's law begin to be stretched to their physical limits (see appendix), we could see a tapering of the efficiency gains of the past. And, if this happens, implications for the power industry and electricity grids could be considerable.

Chart 9. ICT power range estimates of global electricity (2025)



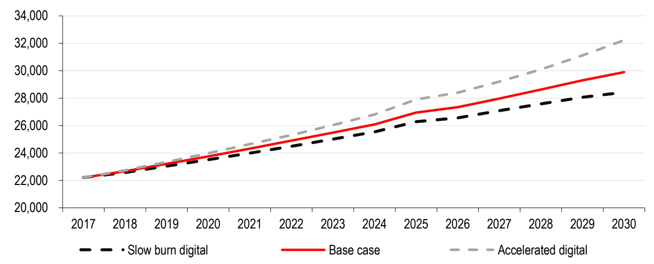
Source: HSBC estimates

Energy scenarios in a digitised landscape…

There are already signs that power needs for the digital economy are outpacing traditional electricity demands. For example, a 2014 study, Trends in worldwide ICT electricity consumption, estimated global electricity use by ICT grew at 7% per year between 2007 and 2012 but overall electricity only grew at 3%.[4]

The term digitisation includes many moving parts. Global electricity usage in ICT can be broken down into manufacturing and use. The key moving pieces are: data centres, networks (fixed and wireless) and devices. Chart 10 takes a top level view of global power.

Chart 10. Global power demand



Source: HSBC estimates, IEA

How much of the global power demand do we think digitisation has been using so far, and what direction might it traverse over the coming decade? We outline this in the three different scenarios that we've modelled.

Please contact your HSBC representative or email Research.Direct@hsbc.com for more information on how to access the full report and our three scenarios.

[4] "Trends in worldwide ICT electricity consumption from 2007 to 2012", Van Heddeghem et al., 2014

Appendix

A brief history of technology laws and implications for power in the digital world

In essence, one could suggest that the computerisation of society started in the 1960s, and that part of our economic growth has been supported by exponential computational technology laws such as Moore's law and Koomey's law. This, together with zero marginal cost impacts – in other words, an era of nearly free goods and services through digitisation (eg streaming video vs physical DVDs, or physical book vs e-books) – means these technology laws have been important, especially so during the rise of the cloud era post the iPhone moment in 2007. If we start hitting the physical limits of the current technology stack, this could impact things like energy efficiency, which we have so far taken for granted, and affect growth in unforeseen ways.

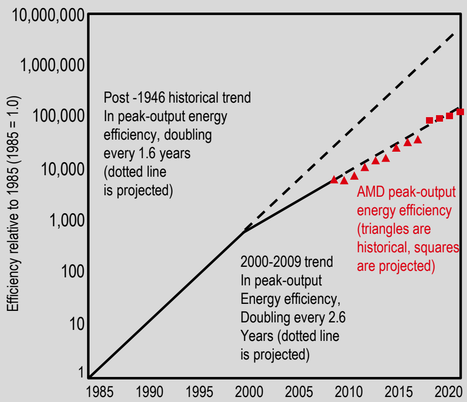
In the 1960s, one of the co-founders of Intel, Gordon Moore, discussed in a paper how the number of transistors on a microchip could be doubled every 1.5 years. At the same time, the cost could also be reduced over the time horizon. This observation became known as **Moore's law**. It's understood that Moore's law has been slowing of late (from doubling every 1.5 years to 2 or more years), as the size of transistors reaches the limits of physics. This partly explains why we have seen different types of chips being manufactured, like dual, quad and hexa-core, instead of single cores, as these enable multi-thread processing (e.g. simultaneous computation).

Moore's law is important for data centres, as increasing the power on chips implies more heat is generated by these components – requiring more energy for powering cooling resources within data centres.

Koomey's law, established by Jonathan Koomey, a Consulting Professor at Stanford University, is another principle governing computing hardware. It states that historically the number of computations (per joule of energy dissipated) doubles every 1.57 years, in approximate tandem with Moore's Law (doubling every 1.5 years). However, in 2011, Koomey's law was found to have slowed to 2.6 years from 1.57 years. Doubling every 1.57 years means a hundred-fold increase in efficiency every decade, but doubling every 2.6 years implies only a sixteen-fold increase over the same time.

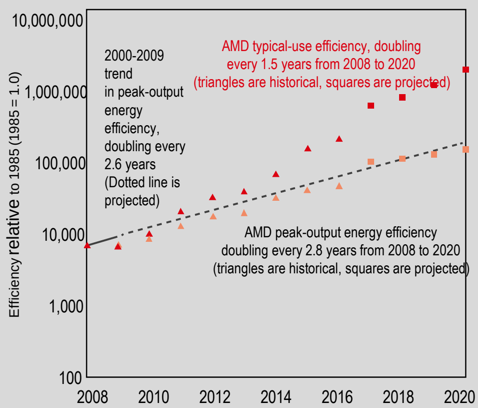
Koomey says "as with any exponential trends, this one will eventually end…in a decade or so, energy use will once again be dominated by the power consumed when a computer is active. And that active power will still be hostage to the physics behind the slowdown in Moore's Law". Koomey's law isn't broken yet, but is certainly observed to be slowing down (chart 9) and could have an underappreciated impact on global energy demands in the digital space.

Chart 11. Data centre energy use could be impacted by "peak-output" energy efficiency slowdown in Koomey's law



Source: "Implications of historical trends in the electrical efficiency of computing", IEEE, 2011

Chart 12. ...whereas energy efficiency in mobile devices gets better due to "typical-output" energy efficiencies



Source: "Efficiency's brief reprieve: Moore's Law slowdown hits performance more than energy efficiency", IEEE, 2015

The slowing of Koomey's law could have an impact on data centre energy efficiency – in a similar fashion to the slowing down of Moore's law, like Intel's tick-tock or "Process, Architecture, Optimization". In other words, Intel is having to intentionally slow down Moore's law as a compromise and an optimisation choice in the product cycle.

Koomey's law looks at energy use in peak operation times or "peak-output", and here the difference in peak usage becomes important. Mobile devices operate at computational peaks at less than 1% of the time, enterprise data services function at peak computations at less than 10%, whereas cloud-based internet services operate at computational peaks 50% of the time.

R&D has focused on exploring different techniques to drive energy efficiency gains in terms of "typical-use efficiency" (e.g. optimising power management during idle and sleep times) rather than "peak-output energy efficiency" (i.e. lowering energy consumption from computations). The fact that mobile devices are not operating at "peak output" for 99% of the time partly helps to explain why energy efficiency of mobile devices is set to continue improving (chart 10), whereas the energy efficiency of powering data centres for cloud computing could decline going forwards (chart 9).

Nevertheless, there is possible light at the end of the tunnel for computation and energy, though this is dependent on new architectures and technologies being built to enable new energy efficiencies to be found – sometimes referenced as 'beyond CMOS' (complementary metal-oxide semiconductor).

Disclosure appendix

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From 23rd March 2015 HSBC has assigned ratings on the following basis:

The target price is based on the analyst's assessment of the stock's actual current value, although we expect it to take six to 12 months for the market price to reflect this. When the target price is more than 20% above the current share price, the stock will be classified as a Buy; when it is between 5% and 20% above the current share price, the stock may be classified as a Buy or a Hold; when it is between 5% below and 5% above the current share price, the stock will be classified as a Hold; when it is between 5% and 20% below the current share price, the stock may be classified as a Hold or a Reduce; and when it is more than 20% below the current share price, the stock will be classified as a Reduce.

Our ratings are re-calibrated against these bands at the time of any 'material change' (initiation or resumption of coverage, change in target price or estimates).

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For each stock we set a required rate of return calculated from the cost of equity for that stock's domestic or, as appropriate, regional market established by our strategy team. The target price for a stock represented the value the analyst expected the stock to reach over our performance horizon. The performance horizon was 12 months. For a stock to be classified as Overweight, the potential return, which equals the percentage difference between the current share price and the target price, including the forecast dividend yield when indicated, had to exceed the required return by at least 5 percentage points over the succeeding 12 months (or 10 percentage points for a stock classified as Volatile*). For a stock to be classified as Underweight, the stock was expected to underperform its required return by at least 5 percentage points over the succeeding 12 months (or 10 percentage points for a stock classified as Volatile*). Stocks between these bands were classified as Neutral.

*A stock was classified as volatile if its historical volatility had exceeded 40%, if the stock had been listed for less than 12 months (unless it was in an industry or sector where volatility is low) or if the analyst expected significant volatility. However, stocks which we did not consider volatile may in fact also have behaved in such a way. Historical volatility was defined as the past month's average of the daily 365-day moving average volatilities. In order to avoid misleadingly frequent changes in rating, however, volatility had to move 2.5 percentage points past the 40% benchmark in either direction for a stock's status to change.

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